ECONOMIC GEOLOGY

WITH WHICH IS INCORPORATED

THE AMERICAN GEOLOGIST

VOL. VI JUNE, 1911 No. 4

THE LITERATURE OF ORE DEPOSITS IN 1910.

FREDERICK LESLIE RANSOME.

As it is manifestly impossible in a brief paper to refer to every publication on ore deposits that appeared last year, some plan of selection is necessary. The one here followed is to choose for special mention those contributions that bear on the genesis of ores and those that collectively will give the reader the clearest and most comprehensive view of the general trend of thought in this branch of science.

Geologists have long agreed that the chief agent in the deposition of ores is water, but they are by no means unanimous as to the source of this underground solvent. For many years the efficacy of heated meteoric waters to extract metallic constituents from the rocks and to deposit these in favorable situations as ores was scarcely disputed. During the past decade, however, there set in a strong reaction to the view that the ore constituents and the water carrying them have issued from cooling magmas, some even maintaining that these emanations constitute final and attenuated differentiation products of the crystallizing intrusive masses. To this view some students have been unable to yield unqualified assent. While admitting that solidifying magma probably expels some water in liquid or gaseous form together with other gaseous constituents, perhaps including some compounds of the metals, they cannot see any reason why water from other than magmatic sources, when heated by intrusive rock and

charged with chemically active constituents expelled from the magma, should not be a very efficient agent of ore deposition. This non-magmatic water may be ordinary meteoric water that has soaked down from the surface, it may be water from the dehydration of sedimentary rocks under the action of pressure, heat and metamorphism, or it may be distilled from various solid rocks heated by intrusion, as indicated by the experiments of Gautier.[1] If magmatic emanations alone were concerned in the deposition of most ore bodies it is difficult to understand why the deposition of ores should not be the regular and invariable accompaniment of the intrusion of certain magmas rather than the somewhat erratic and exceptional occurrences that they actually are.

In so far as the publications of last year relate to this fascinating if rather speculative line of inquiry they weigh against the extreme magmatic hypothesis of ore genesis. O. Stutzer,[2] in a paper before the International Congress on Economic Geology at Düsseldorf, after discussing Brun's work on volcanic exhalations and summing up the results of other investigators, concluded that the magmatic emanations are primarily anhydrous, that they gather water on their way to the surface, that the mineral matter of the so-called juvenile springs is derived partly from solidifying magma and partly by extraction from the rocks traversed.

The notable investigations of Brun[3] although they were not published in their final form until 1911 were previously available in parts as separate papers and may appropriately be referred to in a review of the year 1910. In his monograph Brun records a remarkable series of analyses of gases given off when various lavas are artificially heated to the temperature of explosion and of gases issuing from fumaroles in many parts of the world.

[1] La genèse des eaux thermales et ses rapports avec le volcanisme," *Annales des Mines*, 6 ser., vol. 9, 1906, pp. 316–370. Also this journal, Vol. I., 1906, pp. 688–697.

[2] Stutzer, O., Juvenile Quellen, Int. Kong. Düsseldorf, 1910, Abteil. IV., Vortrag 21, s. 1–8.

[3] Brun, A., "Recherches sur L'Exhalaison Volcanique," Geneva and Paris, 1911.

He finds that the gases from the two sources are similar, that free chlorine and hydrochloric acid are abundant and characteristic constituents, and that water-vapor is absent. He maintains that the white cloud (panache blanc) that hangs over an active cone and which is commonly supposed to be condensed vapor, is really made up of condensed solid particles of volatile chlorides and fluorides, of silica and of sulphur, together with fine rock powder or pumiceous dust. His general conclusions as to volcanoes are: (1) The eruptive paroxysm is anhydrous, (2) the gases exhaled are always of substantially the same character and (3) the presence of water in a volcano constitutes an epiphenomenon. With respect to aqueous fumaroles he concludes (1) The intensity of fumarolic activity is generally proportional to rainfall, (2) circulating waters are arrested in their downward progress by the isogeotherms between 120° and 340° C. He regards the water of aqueous fumaroles as meteoric water (eaux errantes) and remarks that every eruption in which lava reaches the surface means a loss of oxygen from the atmosphere, of water from the lithosphere and an increase in the salinity of the ocean.

Brun distinguishes between the active rocks that yield chlorine on heating and what he calls dead rocks (for example the sedimentary and metamorphic rocks with most granites) which on heating yield gases of a different character, as has been shown especially by R. T. Chamberlin.[1] The very great difference in the compositions of the gases obtained by these two investigators and the distinction made between active and dead rocks are points on which the reader is likely to wish for more light. Moreover, the presence of water in the micas and other minerals of plutonic rocks and the well established connection between granites, pegmatites and certain quartz veins are facts apparently not in harmony with the view that magmas are completely anhydrous and not given sufficient consideration by Brun.

[1] "The Gases in Rocks," Carnegie Institution of Washington, Public. No. 106, 1908.

In his study of the hot springs of Iceland Thorkelsson,[1] although he does not specially discuss the origin of the water evidently considers that it found its way down from the surface. Similarly Hague[2] after a long and thorough study of the geology of the Yellowstone National Park has concluded that its springs and geysers are fed by vadose waters.

An investigation of much interest in connection with the genesis of ores is that of F. Henrich[3] who treated rock-powder CO_2 in water and analysed the extraction products. He found that no constituents wholly withstand attack but that manganese, calcium and iron are the elements removed in greatest quantity as a rule, the proportion of these elements extracted being greater than that of the alkalies. He concludes that mineral springs extract most of their constituents from the rocks and that their contained gases, especially CO_2, are the most efficient factors in bringing the water to the surface. Carlsbad and other similar springs, according to Henrich, are not fed by magmatic water and he doubts the existence of juvenile springs, maintaining with Brun that the extension of open water-bearing fissures down to magmatic sources is an impossibility. It may be remarked in this connection, however, that postulation of a magmatic source for the waters by no means demands the existence of such continuously open channels.

The bearing upon the problem of ore genesis of the foregoing investigations on the source of volcanic gases and thermal waters is too obvious to need explanation.

Among general papers dealing with the enrichment of ore bodies through the agency of downward-moving water, that of

[1] Thorkelsson, T., "The Hot Springs of Iceland," *Mem. de l'Acad. Roy. des Sciences et des Lettres,* Copenhagen, 1910, 7me sér., Section des Sciences, t. VIII., pp. 181–264.

[2] Hague, Arnold, "The Origin of the Thermal Waters in the Yellowstone National Park," *Science,* New Ser., Vol. 33, 1911, pp. 553–568.

[3] "Über die Einwirkung von kohlensäurehaltigen Wasser auf Gesteine und über den Ursprung und den Mechanismus der kohlensäureführender Thermen," *Zeits. für praktische Geologie,* Vol. 18, 1910, pp. 85–94.

W. H. Emmons[1] is probably the most important. His main thesis is that gold is soluble in cold dilute solutions containing chlorides when manganese oxide is present and consequently that manganiferous gold deposits in process of oxidation and erosion are more likely to become enriched by solution and redeposition of the gold than to give rise to placer deposits. He shows that ordinary mine waters contain sulphates and chlorides as their most abundant constituents. Chemical experiments, carried out by A. D. Brokaw in connection with this investigation, prove that gold is actually dissolved by cold solutions containing ferric chloride, sodium chloride or hydrochloric acid at from one tenth to one twenty-fifth normal strength in the presence of manganese dioxide, the essential feature being the combination of the gold with nascent chlorine.

The probable application of this process in gold and silver deposits that are undergoing oxidation is discussed in detail and the paper closes with a careful review of the literature descriptive of American gold districts with special reference to the effect of manganic compounds in effecting secondary enrichment in gold.

In a paper read before the Canadian Mining Institute, F. L. Ransome[2] brought together and discussed the criteria for determining the presence or absence of effects produced in an ore body by downward sulphide enrichment. The interest of the subject rather than anything especially novel in the paper led to an extended discussion in the pages of ECONOMIC GEOLOGY.[3]

The subject of the classification of ore deposits has had some attention from German workers[4] but the results have not been especially illuminating. Krusch attempts to apply to ores the

[1] Emmons, W. H., "The Agency of Manganese in the Superficial Alteration and Secondary Enrichment of Gold Deposits in the United States," *Trans. Am. Inst. of Min. Eng.*, Vol. 41, 1910, pp. 767–837.

[2] "Criteria of Downward Sulfide Enrichment," this journal, Vol. 5, pp. 205–220, 1910. Also *Proceedings of Canadian Mining Inst.* for 1910.

[3] See Vol. 5, 1910, pp. 387, 390, 477, 479, 484, 558, 678, and 681.

[4] Adam, J. W. H., "Versuch einer neuen Behandlungsart der Erzlagerstättenlehre," *Zeit. f. prak. Geol.*, Vol. 18, 1910, pp. 5–10. Krusch P., Über primäre und sekundäre Metasomatische Prozesse auf Erzlagerstätten," *Zeit. f. prak. Geol.*, Vol. 18, 1910, pp. 165–180.

zones and belts of metamorphism as conceived by Van Hise for rocks in general. Thus he distinguishes *primary metasòmatism* and *secondary metasomatism,* the latter being divisible into *cementation metasomatism* (zone of sulphide enrichment) and *oxidation metasomatism* which is characterized by the occurrence of colloidal minerals.

During the last few years De Launay has applied to Asia the same idea of close genetic relationship between orogeny, petrology and ore deposition developed in his "Les Richesses Minérales de l'Afrique"[1] and in his "La Metallogénie de l'Italie."[2] His final work, "La Géologie et les Richesses Minérales de l'Asie," was not published until the current year, but the appearance of a long preliminary paper[3] in 1909 brings his results within the range of the present review. His book of about 800 pages consists of three parts. (1) A review of the history and present condition of the mining industry in Asia, (2) an account of the geology of Asia both in general and by regions, and (3) a discussion by regions of the metallurgy (métallogénie). Part I. may be passed over without comment. Part II. is an elaborate and apparently very thorough compilation and summary of existing knowledge of the geology of Asia, with references to sources. Part III. opens with a preamble in which de Launay sketches the general scheme of metallization which in a broad way appears to him to afford the most reasonable explanation of the facts of ore occurrence. According to his view, a region of metallization prior to erosion is normally underlain at a depth of from ten to thirty kilometers by a zone of crystallization in which is formed granitic rock with aureoles of gneissic metamorphism. The kind of metallization associated primarily with rocks of these types consists of pyritic impregnations and innumerable pyritic veinlets in the schistose rocks, with local aggregations of the pyrite into great masses. Gold and sometimes

[1] Paris, 1903.

[2] Congrès Géol. Internat. Xème Session, Mexico, 1906, premier fasc. 1907, pp. 555–694.

[3] La Métallogénie de l'Asie Russe," *Ann. d. Mines,* Vol. 15, 1909, pp. 220–295 and 303–427.

copper or nickel are associated with iron sulphide. Deposits of this character are exposed only after long and deep erosion and consequently are to be seen today in the primitive crystalline platforms of Siberia and India.

At less depth than the preceding zone, according to De Launay, are formed the granulitic rocks of French petrographers, the ophitic rocks and the porphyries. With these are characteristically associated lead-zinc veins as exemplified in the Urals, the Kirghise steppe, the Altai Mountains, Indo-China and southwest China.

At still less depths solidified the microlitic rocks, such as the andesites, associated with veins similar to those of the preceding zone but accompanied by quartzitic gold-silver veins. Montana (this being clearly a mistake), Colorado and Mexico are given as classic localities for this type which is said to occur also in Japan.

Finally at still less depth takes place folding of the type of the Jura which is unaccompanied by important metallization. Active volcanism moreover is not associated with ore deposition near the surface. Thermal springs according to De Launay are relatively superficial and transient phenomena.

De Launay's volume brings together a vast quantity of information on the geology and ore deposits of Asia but this great mass of data appears to be rather loosely articulated with his main hypotheses. Consequently while most readers are likely to feel that there may be some truth in his views they probably will not accept them as being satisfactorily demonstrated. They are at present suggestive rather than convincing.

In connection with this retrospective glance over the broader and more general results achieved during the past year reference may appropriately be made to the description by Lindgren, Graton and Gordon[1] of pre-Cambrian veins, carrying chiefly gold and copper, in New Mexico and the establishment of criteria for distinguishing these ancient veins from those of later geological

[1] "Ore Deposits of New Mexico," Profess. Paper U. S. Geol. Survey, No. 68, 1910.

periods. Here too may be mentioned, although the principal results of this work were published in 1909, the recognition and characterization of the new type of alunitic gold deposits typically exemplified by those of Goldfield, Nev.[1]

On the whole the year 1910 was not conspicuous for notable advances in our knowledge of ore genesis. To a large extent, as will presently be seen, the energies of economic geologists were directed to immediately practical ends rather than into theoretical channels. It was a period during which nations alarmed by the growing consumption of their mineral resources were anxiously engaged in estimating their reserves or in searching for new supplies. This feeling of concern for the future found notable expression in the great work[2] on the iron ore resources of the world published by the Eleventh International Geological Congress, which met last year at Stockholm. About fifty specialists coöperated in this attempt to estimate the available supplies of iron ore and the two large volumes and atlas not merely present the ascertained or estimated quantities of this basal commodity but bring together in summary form nearly all that is known of its geological occurrence. In this country many of the economic geologists attached to the federal survey have been occupied in the measurement and evaluation of mineral resources but the demands have been more urgent in connection with deposits of coal, oil and phosphates than with the metalliferous ores. Although scientific men are likely to chafe under the necessity of devoting time to the calculation of the size and value of a deposit, nevertheless experience in this work, if not too protracted, is a form of scientific discipline not to be despised. Some practise in reducing facts to figures is likely to lead to closer observation, more accurate thinking and keener discernment of what is essential when attention is turned to purely scientific problems.

[1] "Geology and Ore Deposits of the Goldfield District, Nevada," Profess. Paper U. S. Geol. Survey No. 66, 1909. Also this journal, Vol. 5, 1910, pp. 301–311 and 438–470.

[2] "The Iron Ore Resources of the World," Stockholm, 1910. Reviewed in this journal, Vol. 5, 1910, pp. 689–693.

Among publications dealing with the geology and varied ore deposits of particular regions or districts probably the report by Lindgren, Graton and Gordon, on the deposits of New Mexico is the most important. As already indicated, it calls attention to the possibility of distinguishing pre-Cambrian deposits from those of later ages in the same region. Moreover, it marks a new departure in the publications of the U. S. Geological Survey in that it deals comprehensively with all of the metalliferous deposits in a territory. In the case of New Mexico so little detailed work had previously been done that the authors apparently felt impelled to devote more space to purely local descriptions of unimportant deposits than was perhaps consistent with the most successful treatment of the whole. In subsequent similar reports on the different western mining states this difficulty will not be so great. By bringing together and coördinating the results obtained by the detailed investigation of separate districts and by considering them all in the light of the geological development of the whole region not only are relations of scientific importance disclosed and new lines of research indicated but a distinct service is rendered to all interested in obtaining reliable and modern information on the essential conditions of ore deposition in a given broad region.

Under the head of regional description may be mentioned also a rather full account of the metalliferous deposits (exclusive of iron) in Algeria by M. Dussert,[1] a brief paper on the ore deposits of Uruguay by C. Guillemain[2] and a similar one on Argentina by R. Stappenbeck.[3]

Iron-ore deposits, as already noted, received much attention in 1910. In addition to the comprehensive work previously mentioned there appeared a number of important publications dealing with the Scandinavian ores. The views of H. Sjögren and

[1] "Étude sur les gisements métallifères de l'Algérie," *Ann. de. Mines,* Vol. 17, 1910, pp. 24–84 and 91–203.

[2] "Lagerstätten in der Republik Uruguay," *Zeits. f. prak. Geol.,* Vol. 18, 1910, pp. 189–192.

[3] "Übersicht über die nutzbaren Lagerstätten Argentiniens und der Magelhaensländer," *Zeits. f. prak. Geol.,* Vol. 18, 1910, pp. 67–81.

H. Johansson on the genesis of the older pre-Cambrian Swedish ores, published a few years ago have recently been reviewed by Lindgren,[1] in a way to serve as a good introduction to the later works, chief among which is Per Geijer's handsome monograph on the ores of the Kiruna district[2] with accompanying papers. A remarkable feature of this work is the fact that the cost of fieldwork and publication was borne by the enlightened and public-spirited company that operates the mines under the management of Dr. Hj. Lundbohm.

Geijer's conclusions[3] are that the iron ore, consisting mostly of magnetite with apatite as the chief gangue mineral, and syenite-porphyries as the country rocks, was a late differentiation product of the syenitic parent magma and spread over the surface as a lava flow.

Many excellent papers on the Scandinavian iron-ore deposits are included in the Guide to the Excursions in connection with the Eleventh International Geological Congress at Stockholm. Here the Gellivare iron mountain is described by A. G. Högbom, the Kiruna district by Hj. Lundbohm, the Dannemora, and Persberg districts by H. Sjögren, and the Flogberget and Grängesberg deposits by H. E. Johansson. Vogt[4] recently has described the titanic iron ores at Rödsand in Norway. He shows that the so-called titano-magnetite is a mechanical mixture of magnetite and ilemite. The ores, which are notable as containing corundum whereas in most similar ores in Norway the alumina has crystallized with magnesia as spinel, are enclosed in schistose gabbro which in turn is surrounded by strongly squeezed granite. The granite, gabbro and ore are held to be successive differen-

[1] This journal, Vol. 5, 1910, pp. 494–498.

[2] Geijer, Per, "Igneous Rocks and Iron Ores of Kiirunavaara, Luossavaara and Tuolluvaara," Stockholm, 1910. Carlheim-Gyllensköld, V., "A brief Account of a Magnetic Survey of the Iron Ore Field of Kiirunavaara," Stockholm, 1910. Sjögren, Otto, "Bidrag til Kirunaområdets Glacialgeologi," Stockholm, 1910.

[3] An author's abstract of the monograph appears in this journal, Vol. 5, 1910, pp. 699–718.

[4] Vogt, J. H. L., "Ueber die Rödsand-Titaneisenerzlagerstätten in Norwegen," *Zeits. f. prak. Geol.*, Vol. 18, 1910, pp. 59–67.

tiation products from one granitic magma. In contrast to this occurrence the nearly titanium-free ores of the Gellivare type (including the deposits at Norrbotten, Solberg, Lyngrot, Smorten and Madmorderen in Norway with some in the United States) and of the Syd-varangen type (including many small deposits in Norway) are in direct contact with siliceous eruptive rocks, generally granite. Vogt concludes, however, that all are magmatic differentiation products in connection with which the intermediate gabbro stage, present at Rödsand, is lacking.

Although deposits of low-grade copper ore have for the last two or three years been exploited with great activity and have been carefully studied, the results of their scientific investigation have not yet been extensively published.

In the report by Lindgren, Graton and Gordon, already referred to, is an interesting discussion of the origin of the copper deposits of the "Red Beds." The copper is thought to have been derived from the erosion of the pre-Cambrian deposits and to have accumulated in diffuse condition, partly by chemical precipitation, with the sediments. The present "Red Bed" deposits are the result of concentration along certain beds or in fissures by circulating atmospheric waters charged with chlorides and sulphates. In this way is explained the deposition of chalcocite instead of chalcopyrite and bornite.

A valuable and interesting account of the pyritic deposits of the Huelva district, Spain, by A. Moncrieff Finlayson appeared lately in this journal.[1] He shows that these deposits, whose genesis has been much discussed, were deposited by solutions that, after the cessation of igneous activity, rose along great thrust planes and replaced the sheared and crushed rock by ore. The primary ores were enriched by downward-moving waters during a long period of erosion. Another important paper is that by L. C. Graton on the copper ores of Shasta County, California.[2] These occur as large masses of pyritic ore enclosed for the most

[1] Vol. 5, 1910, pp. 357–406.

[2] Graton, L. C., "The Occurrence of Copper in Shasta County, California," in "Contributions to Economic Geology," Bull. U. S. Geolog. Survey No. 430, 1910, pp. 71–111.

part in alaskite porphyry. They yield from 3 to 3.5 per cent. of copper with from $1.50 to $2.00 per ton in gold and silver. The ore has been deposited by metamorphic replacement of fractured and crushed portions of the alaskite porphyry. Mr. Graton concludes that the ores and the water whereby transportation and deposition were effected were alike supplied by the alaskite-porphyry magma as a final liquid differentiation product. Decision as to the basis for this explanation may well await the appearance of Mr. Graton's final report, of which this is an advance summary.

Another important paper on copper deposits is that of S. F. Emmons on Cananea.[1] These ores are believed to have been deposited by highly heated solutions emanating from cooling magmas. Two periods of deposition are recognized, one in which the emanations were above the critical point of water and one in which the temperature of the solutions was such that they could exist in liquid form. Secondary enrichment has been most effective in the deposits formed at the lower temperature.

Knowledge of Mexican copper deposits has been increased also by Bergeat's[2] study of the contact metamorphism in connection with the intrusion of the granodiorite of Concepción del Oro. He shows that the contact action has been accompanied by extensive migration of material both from and into the eruptive rock which has been locally changed to garnet of the same kind as that developed in the limestone. The conditions are similar in some respects to those described by Spurr and Garrey[3] at Velardeña although Dr. Bergeat makes no reference to this paper. The ore deposits near Concepción del Oro are: (1) Contact metamorphic deposits with chalcopyrite as the most char-

[1] Emmons, S. F., "Cananea Mining District of Sonora, Mexico," this journal, Vol. 5, 1910, pp. 312–356. Reprints of this paper distributed by the Cananea Consolidated Copper Co. were accompanied by detailed geologic maps.

[2] Bergeat, A., "La granodiorite de Concepción del Oro en el estado de Zacatecas y sus formaciones de contacto," *Boletín del Instituto Geológico de México*, No. 27, 1910.

[3] "Ore Deposits of the Velardeña District, Mexico," this journal, Vol. 3, 1908, pp. 688–725.

acteristic sulphide, exemplified by the important mines at Aranzazú, (2) the copper bearing vein El Placer in the grandiorite, (3) lead-zinc deposits in limestone and (4) auriferous quartz veins. Classes (1) and (2) are of pneumatolytic origin, are directly connected with the intrusion and are distinguished as perimagmatic. The deposits of class (3) are of hydatogenetic origin and were deposited by solutions capable of penetrating to some distance from the magma. They are called apomagmatic. The veins of class (4) are interpreted as of later origin, the gold being derived from the contact deposits.

The literature of gold deposits has not been greatly enriched during the past year. A report by Ransome, Emmons and Garrey[1] describes the very elaborate faulting of a thick series of Tertiary lavas, chiefly rhyolites, and the rather weak metallization that followed the fissuring. Brief accounts of other gold deposits in Nevada may be found in the reconnaissance bulletins by W. H. Emmons[2] and F. L. Ransome.[3] A short preliminary account of the Randsburg District, California, by F. L. Hess, appears in the general economic bulletin[4] of the U. S. Geological Survey, for 1909, a publication that includes also many brief and preliminary papers on deposits of metals other than gold. Another bulletin[5] contains similar papers on the gold and other metallic deposits of Alaska. The occurrence of the remarkable selenium-bearing gold ores of the Republic district, Washington, has been studied by J. B. Umpleby[6] and his report is of additional interest as being the first publication of the Washington State Geological Survey. Note may be made also, in this connection, that the year 1910 saw the organization of the

[1] "Geology and Ore Deposits of the Bullfrog District, Nevada," Bull. U. S. Geol. Survey No. 407, 1910.

[2] "A Reconnaissance of Some Mining Camps in Elko, Lander and Eureka Counties, Nevada," Bull. U. S. Geol. Survey No. 408, 1910.

[3] "Notes on Some Mining Districts in Humboldt County, Nevada," Bull. U. S. Geol. Survey No. 414, 1910.

[4] Bull. U. S. Geol. Survey No. 430, 1910.

[5] "Mineral Resources of Alaska," Bull. U. S. Geol. Survey No. 442, 1910.

[6] "Geology and Ore Deposits of Republic Mining District," Bull. Geol. Survey of Washington No. 1, 1910.

Geological Survey of Tennessee which under the able and scientific directorship of Dr. G. H. Ashley is certain, if properly supported, to be a credit to the state.

Important papers on foreign occurrences of gold deposits were not very numerous in 1910. Hall[1] has given a good description of the Pilgrims Rest or Lydenburg district where the so-called reefs follow very persistently the bedding planes in a series of dolomites and are explained as having been formed by replacement and De Launay[2] has described the gold veins of northern Madagascar.

Lindgren's[3] interesting discovery of anhydrite as a gangue mineral at the Cactus mine in Utah, associated with tourmaline, quartz and siderite was an important addition to our knowledge of the mineralogy of ore deposits although, as he remarks, the mineral has been noted in five or six localities in Europe in metalliferous veins. The Cactus occurrence suggests deposition at high temperature and pressure from solutions containing an unusual quantity of sulphuric acid or sulphates.

A notable addition to the text-books on ore deposits is the work by Beyschlag, Krusch and Vogt,[4] of which the first volume dealing with ore-deposits in general, magmatic segregations or differentiation products, contact deposits, tin deposits and quicksilver deposits, appeared in 1910. In this book many pyrite deposits, including those of Rio Tinto, are treated as intrusive masses. Two more volumes are in preparation. The publication of new editions of Beck's well-known "Erzlagerstätten" and of Ries's "Economic Geology" also deserve mention in a record of the year.

In conclusion, attention may again be called to the fact that the foregoing review is not intended as an exhaustive summary

[1] A. L. Hall, "The Geology of the Pilgrims Rest Gold Mining District," Transvaal Mines Dept., Geological Survey, Memoir No. 5, 1910.

[2] "Les filons d'or et les roches éruptives de la région d'Andavakoera à Madagascar," *Soc. Geol. France, Compt. Rend.*, No. 4, 1910.

[3] Anhydrite as a Gangue Mineral." this Journal, Vol. 5, 1910, pp. 522–527.

[4] "Die Lagerstätten der nutzbaren Mineralien und Gesteine," Vol. 1, Stuttgart, 1910.

of the literature. Doubtless many papers are omitted that might have been mentioned by others in attempting to cover the same field. The intention has been to show the main trend of thought in the study of ore deposits and the general extent of the progress made in their investigation during the past year. In neither respect was the year especially noteworthy.

RAPID EXAMINATION OF WATER IN GEOLOGIC SURVEYS OF WATER RESOURCES.[1]

R. B. DOLE.

INTRODUCTION.

As one phase of its researches into problems of economic geology, the United States Geological Survey during the past eight or ten years has been conducting systematic investigations of the quantity, distribution, availability, and quality of underground waters in various parts of the United States. These studies have been carried over a greater part of the Atlantic and gulf coastal plains, over selected areas in the Middle West, and into many of the isolated basins of the arid and semi-arid districts extending from the Rocky Mountains to the Pacific coast.

The elements that enter into the general water-supply problem in the various fields differ widely in their relative proportions, though the same principles are applicable everywhere, the weight given to one or the other of the elements depending on the urgency of the need of the developed waters and on the uses to which they are to be applied. Along the Atlantic seaboard deep-lying waters may be developed for municipal or manufacturing supplies. Farther inland the principal application of water from springs and wells may be for farm use; as surface streams are abundant and their purity high in many such areas, underground waters are of relatively little importance. In the Middle West, however, waste products from industrial establishments pollute many streams of only moderate flow, and so water users are driven to investigation of underlying ground waters. These ground waters may be procured, in glaciated areas at moderate depths in sufficient abundance and with moderate mineral content; outside the glacial zone they may lie in deep aquifers of limited distribution and may carry high amounts of dissolved

[1] Published by permission of the Director, United States Geological Survey.

solids. West of the Mississippi in the plains region and in the more truly arid districts farther west surface streams may exist only for a short time after storms. Here irrigation may be necessary for a short period each year and the underground waters must be drawn on. Their suitability for this and for other purposes then becomes a matter for as careful investigation as their quantity and the depth at which they exist. These conditions, typical of the great plains, extend southward into the northern part of the coastal plain of Texas, where surface waters may be meager in amount and underground waters relatively abundant, but doubtful in quality. Under the bolson plains and in the valleys of the Great Basin, where surface waters in sufficient quantity and of sufficiently regular flow rarely exist, saturated gravels capable of yielding water to support mining districts or small sections of intense agricultural development have been discovered in many isolated areas. Plains of similar type exist in central and southern California where rainfall is less meager but yet insufficient to permit cultivation of the more profitable crops without artificial application of water.

The geologists of the survey in their investigations of the varying conditions controlling the distribution of water resources have been confronted from the beginning, as one of the elements of their problem, with the quality of the waters when once developed; that is, with the quantity and proportion of the dissolved substances, because on these factors depends the availability of the water. The necessity of carefully considering this factor in the general classification of water resources has led to organization of a group of investigators who have devoted themselves especially to study of the economic value of waters, to the distribution of their mineral content, and to the effect which it has on the uses of natural waters.

Along this line of investigation certain rapid methods of testing have been devised which have proven valuable for the particular purposes for which they were designed, and have yielded results which are believed to be of great practical utility and of sufficient scientific accuracy to be worth presentation in the hope

that they will prove applicable by workers in other organizations dealing with similar problems.

Experience in typical, widely separated areas has brought out forcibly the fact that a few analyses of water from widely scattered wells do not give a correct idea of the general character of any given water over an extended area; in other words typical samples of water can not be collected. The amount and the composition of mineral matter in waters presumably drawn from the same stratum differ to a great extent because of local modification in material, seepage from other formations, and entrance of water through leaky casings. Shallow wells are subject to more noticeable modification by local conditions, but deep wells on the other hand are more likely to be affected by admixtures of water. The amount and relative composition of the mineral matter in a stream continually are changed from place to place along its course by tributaries, and they also are affected from day to day at a given point by fluctuations in the proportion of affluent ground water and in other conditions. Even the water of Mississippi River, the largest stream in the country, varied 40 per cent. during a year in its content of dissolved matter, and floods or droughts in its tributary basins caused just as great variations in the composition of the residues.

Though it may be recognized that single samples of water are not typical in the sense of showing the general quality of supplies in extensive areas, the cost of shipping large numbers of samples to a laboratory and submitting them to complete analysis is out of the question in preliminary surveys. The alternative, therefore, presents itself of testing a great many waters as correctly as such work can be performed in the field and of making general conclusions from this large number of approximate estimates, amplified and corroborated by a few laboratory analyses. The methods for the examination of water described by M. O. Leighton[1] were proposed for such rapid, inexpensive work, and as they have been successfully used for several years in different

[1] "The Field Assay of Water," Water-Supply Paper U. S. Geol. Survey, No. 151, 1905 (edition exhausted); see also *Engineering News*, June 8, 1905.

parts of the world, it is opportune to show how the results may be translated.

Field methods for water examination should never displace laboratory analyses when such analyses can be made, and nothing in this article should be interpreted as indicating that field tests rival laboratory tests in accuracy or in general usefulness. Precise estimation of inorganic constituents is necessary for economical operation of water-purification plants, for proper valuation of waters before their extensive industrial use, and in study of certain geologic problems. A large and legitimate field of activity is, however, open to methods that give usable results quickly though approximately. It should be added that the results of field assays have no sanitary significance whatever.

ANALYTICAL PROCEDURES.

Procedures for the estimation of iron, calcium, turbidity, color, total hardness, sulphates, chlorine, carbonates, and bicarbonates were described by Mr. Leighton. Several other special procedures have since been used to a limited extent, among which may be mentioned estimation of acidity by titration with tablets of sodium carbonate in presence of methyl orange. As the calcium method can not be relied on to do more than indicate whether waters are high or low in calcium its results should not be expressed in figures. The iron test is likely to give low results because of incomplete oxidation of ferrous compounds by nitric acid in the cold, but fortunately the small amount of iron in most natural waters makes its determination unnecessary in reconnaissance. If means are at hand for heating the acidified solution the iron estimate is fairly accurate even in waters of high iron content. Estimates of color and turbidity are usually unnecessary on ground waters, though during the fall of 1910 the writer was able to locate by means of color determinations a considerable area of wells affected by decomposition of organic deposits in an old lake bottom. The other procedures are strictly applicable to estimation of the inorganic constituents of ground waters, and as Mr. Leighton's report is no longer available discussion of the

accuracy and interpretation of the methods will be prefaced by a brief review of them with some non-essential modifications suggested by practice.

Total Hardness.—Total hardness is determined by adding to a measured amount of the water tablets containing a constant amount of sodium oleate until the liquid after vigorous shaking forms a foam that does not break in five minutes while the bottle rests in a horizontal position. The titration is performed in an eight-ounce bottle with a hemispherical bottom and the tablets are triturated by means of a long-handled glass pestle. Quarters of a tablet should be used on approaching the end-point. The results are expressed in parts per million of $CaCO_3$, the conventional form for figures denoting hardness. The tablets, each of which is equivalent to about 1.5 mg. $CaCO_3$, are standardized by comparison with a solution of calcium chloride. This test on 50 cubic centimeters of water gives sufficiently satisfactory results for hardnesses lower than 200 parts per million. The quantity of insoluble soaps formed in waters harder than that render dilution advisable. If the hardness is between 200 and 400 parts the water may be diluted to one-half strength, and if between 400 and 1,000 parts to one-tenth strength with distilled water. Grinding the tablets is so laborious and time-consuming that use of an alcoholic soap solution is economical if a bottle of it can be carried. A convenient strength can be made by dissolving 10 grams of Castile soap in one liter of dilute alcohol. Such solution has been used by the writer in a glass-stoppered 25-c.c. burette of large diameter with much saving of time.

Sulphates.—About 100 cubic centimeters of the water is slightly acidulated with hydrochloric acid (1–1), about 1 gram of crystals of barium chloride is added, and the cold mixture is vigorously shaken until the crystals are completely dissolved. This precipitates barium sulphate in a very finely divided state, and imparts to the liquid a turbidity the degree of which can be determined in the turbidimeter. This instrument consists essentially of a glass tube enclosed in an open-bottomed brass tube suspended by a large-headed tripod over a standard candle, whose flame is kept

automatically three inches from the bottom of the glass tube. The latter is graduated in millimeters from bottom to top in one scale and in cubic centimeters in another so that it serves both as a depth measure for turbidity readings and as a graduate for general use. A tiny electric bulb with a two-cell dry battery supplies light for another form of turbidimeter, the illumination of which can be so concentrated and toned by crossed slits and a ground glass that readings with it are practically the same as with the candle type. The liquid containing the precipitate of barium sulphate, after being thoroughly agitated, is poured into the graduated tube until the image of the candle flame disappears. This elimination occurs with a given concentration of SO_4 at a definite depth which can readily be located after practice with solutions of known strength. The depth in millimeters of the liquid in the tube is then read across the bottom of the meniscus, and the corresponding amount of the sulphate radicle (SO_4) can be found by reference to a table of equivalents.

The readings should not be made in direct sunlight, and it is preferable to make them in a darkened place or at night. Several comparisons should be made on the same precipitation and the results averaged. Direct readings can be made for amounts between 30 and 400 parts per million of sulphates. Less than 30 parts can be estimated as trace, 5, 10, or 20 parts by the turbid appearance of the mixture. Appropriate dilutions should be made for amounts exceeding 400 parts.

Chlorine.—In the field estimation of chlorine tablets containing uniform amounts of silver nitrate are substituted for the standard solution of that salt used in the laboratory. A measured amount of the water, to which a few drops of a 5 per cent. solution of potassium chromate have been added, is titrated in a glazed white porcelain mortar with the tablets[1] which are crushed and triturated by means of a pestle. The appearance of a permanent red coloration is the end-point, and the chlorine content in parts per million can be calculated from the number and standard of the tablets and the amount of water. The tablets

[1] Manufactured by the Kremers Urban Co., 348 E. Water St., Milwaukee, Wisconsin.

are made in two strengths, one having an equivalent of about 1 milligram and the other about 10 milligrams of chlorine. The weaker tablets cut into quarters should be used with 100 cubic centimeters of water for estimating chlorines less than 50 parts per million, and the stronger ones for commencing the titration of amounts greater than 300 parts per million. It is advisable to dilute before estimating chlorines exceeding 2,000 parts.

Carbonates.—One hundred cubic centimeters of the water with 10 drops of a 1 per cent. solution of phenolphthalein is titrated in a porcelain mortar with sodium acid sulphate tablets each equivalent to about 1 milligram of CO_3. The disappearance of the red coloration is the end-point. Comparatively few waters contain normal carbonates (CO_3); consequently a qualitative test with phenolphthalein to show their absence is usually sufficient.

Bicarbonates.—Two drops of a one tenth per cent. solution of methyl orange are added to the solution in which carbonates have been estimated, and the titration with sodium acid sulphate is continued till a change in the color of the solution from yellow to red indicates the completion of the reaction. The total amount of sodium acid sulphate minus twice that used in the first titration equals the equivalent of the bicarbonates (HCO_3). The tablets can be quartered as in the estimation of chlorine. The titration can be performed more rapidly and accurately in reverse manner. An appropriate number of tablets are dissolved in a fresh portion of the water to which methyl orange is added. The liquid is then titrated with the water until the red color changes to yellow. Carbonates are then determined in a separate portion.

Dilution.—The necessity of diluting highly mineralized waters before performing certain tests is embarrassing because it often adds the bulk and weight of a gallon of distilled water to the equipment. Yet the economy of time and the increase of accuracy thus afforded more than counterbalance the inconveniences. If distilled water can not be carried a water that gives only a slight cloudiness with barium chloride in acid solution and that consumes not more than one silver nitrate tablet and two sodium oleate tablets per 100 cubic centimeters is sufficiently pure to be

used for dilutions, proper allowance of course being made in each test for the impurities. Such water can be found in many districts.

Technique.—Care and experience are essential in use of the field tests, though the manipulative technique of them is simple. Knowledge of the chemical principles underlying the methods is necessary for proper appreciation of the precautions that should be taken in their use and for correct interpretation of the results that are obtained. Therefore they should be performed by men who have had at least elementary chemical training and some practice in volumetric analysis. The figures of a partial assay, unlike those of a complete chemical analysis, are not *prima facie* evidence of their correctness and the tester must establish confidence by his care in performance.

All the apparatus and chemicals necessary for 300 assays can be carried in a case smaller than an ordinary suitcase and it weighs packed less than 30 pounds. The series of tests can be made on a pint of water, but it is better to have at least a quart in order that some tests may be duplicated and the pieces of apparatus thoroughly rinsed with the water to be examined. If the analyst can do so he should carry some bottles for the collection of samples, several extra glass tubes for the turbidimeter, a bottle of soap solution for use in determining hardness, and a gallon of distilled water for diluting strong waters. The most economical routine is to keep the apparatus in camp, or at some central point, and to bring the samples to that place for testing. A single assay can be made in 20 to 40 minutes and one man with some duplicate apparatus can perform thirty assays a day if he does not collect the samples himself. It is advisable to check the field work by analyzing some of the more important waters in the laboratory in the ratio of about one analysis to fifteen or twenty assays.

ACCURACY OF FIELD ASSAYS.

For computation of the actual errors of the field assays fifty-two waters that had been analyzed in the laboratory were tested by the rapid methods.[1] The average error in the test for bicar-

[1] *Eng. News,* Vol. 64, 1910, p. 145.

bonates was found to be a little over 6 parts per million, or 3.5 per cent. with waters containing 100 to 350 parts per million of bicarbonates. The errors range from 0 to 9 per cent., and computation shows that they probably occur in measuring the water.

As one quarter of a silver nitrate tablet in 50 cubic centimeters of water is equivalent to 5 parts per million of chlorine the field results on low chlorines may vary from the true values 5 parts, an error that may be equivalent to 100 per cent., but such discrepancy offers little practical disadvantage because it is as useful in geologic, industrial, or agricultural reconnaissance to know that a water contains less than 10 parts of chlorine, for instance, as to know that it contains exactly 6.7 parts. The average error of 22 estimates in waters containing more than 50 parts of chlorine was found to be 6 parts, or 3.2 per cent.

Twenty-seven of the fifty-two waters contained more than 30 parts of sulphates and the average error of determination in those was 10 per cent. Individual determinations of high sulphates are liable to great error because a difference of 1 cubic centimeter in measuring the water during dilution or a difference of 1 millimeter in measuring the turbidity is proportionately magnified in the result. The best depth for the readings is between 20 and 190 millimeters, corresponding respectively to 328 and 36 parts per million, and the probable error in that range is 8.5 per cent.

A comparison of field assays and laboratory analyses can also be made from the results of a study of underground water conditions in San Joaquin Valley, Cal. About 400 field assays and 50 laboratory analyses were made, and 32 of the laboratory samples were also tested in the field as a check. The two sets are compared in the accompanying table in which only the common determinations are given. The laboratory analyses were performed by Mr. F. M. Eaton, Oakland, Cal.

Bicarbonates have been recomputed to carbonates in both sets of determinations and the result has been added to the normal carbonates, the total CO_3 thus being expressed. This revision is necessary because irregular change in balance of carbon dioxide during the period between collection and examination affects the

TABLE I.

COMPARISON OF FIELD ASSAYS AND LABORATORY ANALYSES.
(Parts per million.)

No.	Sum of Carbonate and Bicarbonate Radicles as CO_3.		Sulphate Radicle (SO_4).		Chlorine (Cl).		Total Hardness as $CaCO_3$.	
	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.
1	24	25	5	0	10	5.4	41	48
2	34	35	Tr.	2.9	5	6.0	51	47
3	37	39	Tr.	0	10	8.0	59	51
4	36	40	10	8.2	15	14	40	42
5	40	44	Tr.	0	30	25	63	76
6	60	66	Tr.	0	10	5.9	84	80
7	50	38	Tr.	0	25	22	87	40
8	67	73	Tr.	0	15	15	151	144
9	60	65	Tr.	0	20	15	111	113
10	50	57	5	7.0	35	35	51	56
11	75	78	Tr.	3.7	15	10	122	114
12	63	65	Tr.	4.1	25	22	3	19
13	73	81	5	:.6	20	19	94	94
14	44	44	20	66	50	48	96	122
15	99	103	Tr.	6.6	5	6.0	24	38
16	64	65	Tr.	0	55	51	68	67
17	80	92	Tr.	0	35	35	44	59
18	87	83	55	45	55	58	250	160
19	46	45	Tr.	0	110	112	28	28
20	147	159	Tr.	0	20	22	11	26
21	115	101	10	0	65	64	68	71
22	185	198	5	4.9	280	279	28	31
23	87	95	400	541	115	128	80	91
24	75	70	50	45	470	433	505	450
25	72	76	800	713	85	86	810	754
26	82	96	760	600	165	153	953	698
27	88	94	830	711	125	122	854	1,027
28	77	68	470	441	445	481	162	120
29	828	962	Tr.	0	490	492	535	655
30	101	108	1,600	718	210	196	1,220	1,240
31	860	841	5	0	1,380	1,418	59	30
32	38	42	5	0	4,110	4.310	1,838	2,773

ratio of carbonates to bicarbonates. Comparison of the two sets of carbonate determinations shows numerical differences ranging from 0 to 134; only one set has a proportionate error exceeding 14 per cent. and the average error of the other 31 sets is 7 per cent.; this is a considerable increase of the average error found in assays in the laboratory, but it is not unreasonable if allowance is made for the optimum conditions of light and other facilities in the laboratory. The usual error in the determinations of low chlorines is 5 parts or less because most of them were estimated

in 50 cubic centimeters of water. The average error of the 11 estimates exceeding 100 parts per million is less than 6 per cent. Field estimates of chlorine should be expressed, therefore, not more exactly than to the nearest 5 parts per million, and not more than three significant figures should be given.

Total hardness expressed for the laboratory analyses has been computed from the amounts of calcium and magnesium by means of the following formula, in which H, Ca, and Mg represent total hardness, calcium, and magnesium respectively in parts per million.

$$H = 2.5\,Ca + 4.1\,Mg.$$

Though this formula expresses the theoretical relation between the amounts of calcium and magnesium and the hardness found by titration with soap and conventionally expressed as $CaCO_3$, actual determinations do not agree exactly because the soap titration is subject to obscure errors and because the form of computation magnifies errors in the estimates of calcium and magnesium. Yet review of the columns of total hardness indicates that the results obtained by titration convey an approximate idea of the amount of the alkaline-earth bases though the proportionate errors of single determinations are fairly high.

The estimates of appreciable amounts of sulphates are too few in number to permit computation of a probable error, but it seems apparent that the precedure gives information regarding the amount of sulphates near enough to the correct values for use in approximate classifications. The field estimate in set no. 14 is obviously wrong and other computations indicate that the laboratory report of sulphates in no. 30 is incorrect.

INTERPRETATION OF FIELD ASSAYS.

The data in reference to mineral ingredients usually desired in preliminary surveys of underground water are the total mineral matter in solution, the nature of the substances present in greatest amount, and the value of the waters for steaming, for irrigation, and for domestic use. The following sections indicate how far

the estimates of carbonates, bicarbonates, sulphates, chlorine, and total hardness obtained by field assay are available for making such classifications.

The common mineral ingredients that affect the value of natural waters are silica, iron, aluminum, calcium, magnesium, sodium, potassium, chlorine, and the carbonate, bicarbonate, and sulphate radicles. Nitrates, phosphates, sulphides, and other substances occur in waters, but they may usually be disregarded, or their insignificance verified by a few laboratory analyses. Silica usually exists in colloidal form and is relatively constant in quantity; iron sometimes affects domestic supplies and certain industrial processes, but both iron and aluminum are rarely present in amounts that need be considered in irrigating or steaming values. Calcium and magnesium are similar in many of their effects and they vary together, calcium usually being the greater in amount. Sodium and potassium likewise are so similar in effect that they are seldom separated in industrial analyses and are reported together as sodium. Carbonates and bicarbonates can be considered under the common term of carbonates. These groupings, rendered possible by the usual mode of occurrence of these substances, greatly simplify classification.

Chief Constituents.—As the principal acid radicles are estimated it is possible to tell directly whether carbonates, sulphates, or chlorides are predominant. The approximate amount of alkaline earths can be computed from the total hardness. Theoretically the amount of calcium and magnesium must be between 0.40 H and 0.24 H; it usually lies between 0.37 H and 0.30 H, as the ratio of calcium to magnesium ranges from 7 to 1; therefore, one third of the hardness is a reasonable estimate of the alkaline earths that will usually be in error less than 10 per cent. The approximate amount of alkalies can be computed by a formula deduced by Mr. Herman Stabler in his excellent article on the classification of irrigating waters.[1]

$$Na = .83\,CO_3 + .41\,HCO_3 + .71\,Cl + .52\,SO_4 - .5\,H.$$

[1] *Eng. News*, Vol. 64, 1910, p. 57.

The symbols represent the amounts in parts per million of alkali (sodium and potassium), and the carbonates, bicarbonates, chlorine, sulphates, and total hardness respectively found by assay. The equation expresses the theoretical relation that the sum of the reacting values of the acid radicles minus the reacting values of calcium and magnesium, which together are one fiftieth of total hardness, gives the combining value of the alkalies; the factor 25 instead of 23, the atomic weight of sodium, is used in order that safe allowance may be made for potassium. The following classification in reference to chief constituents can then be followed.

Calcium.	Carbonate.
	Sulphate.
Sodium.	Chloride.

This scheme could be amplified if that were desirable. The designation of "calcium" indicates that calcium and magnesium are predominant, and "sodium" that sodium and potassium are predominant among the bases, the application of either term being an assumption of the presence of the minor base; similarly the use of "carbonate," "sulphate," or "chloride" shows which acid radicle is predominant. Combination of the two designations classifies the water by type.

Total Solids.—Knowledge of the amount of residue likely to be deposited on evaporation is useful as an index of the total mineral content of a water. This can be computed in several ways, one of which is to calculate the probable amount of saline residue that would be produced by the acid radicles and to add thereto an arbitrary amount for silica, undetermined radicles, and volatile matter. The condition under which the acid radicles could form the greatest amount of salts in solution is when the greatest probable amount of potassium is present; therefore the assumptions that equal amounts of sodium and potassium are present and that calcium and magnesium are absent, constitute an extreme condition representing a maximum saline residue. Similarly the assumptions that equal parts of calcium and mag-

nesium are present and that the alkalies are absent, represent the conditions under which a minimum saline residue would form. A formula based on an average between these two extremes gives an estimate of total solids within 15 per cent. in most natural waters.

$$\text{T.S.} = SiO_2 + 1.73\,CO_3 + .86\,HCO_3 + 1.48\,SO_4 + 1.62\,Cl.$$

"Silica, etc.," has been considered equal to 30 parts per million in waters exceeding 400 parts of total solids and 50 parts in other waters of San Joaquin Valley, these values having been estimated from available analyses. The estimate should not be expressed more closely than to the nearest 10 parts or with more than two significant figures, and it may be expressed in words by the following rating.

TOTAL SOLIDS RATING.

Total solids. Parts per Million.		
More than	Not more than	Classification.
——	150	Low.
150	500	Moderate.
500	2,000	High.
2,000	——	Very high.

Classification for Boiler Use.—The chief troubles caused in boilers by the mineral constituents of waters are corrosion, foaming and formation of scale; consequently, estimates of these three tendencies form bases for classification.

The scale and sludge consist of the substances that are insoluble in the feed water or become so within the boiler under conditions of ordinary operation. They include practically all the suspended matter; the silica, probably precipitated as SiO_2; the iron and aluminum, appearing in the scale as oxide or hydrated oxide; the calcium, precipitated principally in the form of carbonate and sulphate; and the magnesium, found in the deposits principally as the oxide but partly as the carbonate. Over 90 per cent. of scale is usually calcium, magnesium, carbonate, and sulphates. As the scale is therefore a mixture of compounds, which varies in amount and composition under different con-

ditions of operation, any estimate of its amount is approximate. The most satisfactory figure of it from the field tests is found by adding to the total hardness an arbitrary amount for silica as in computing toal solids. If suspended matter is present the turbidity in parts per million may be added. The estimate should be expressed only to the nearest 10 parts and with but two significant figures. Waters may be classified in respect to their scale-forming ingredients by the following table.[1]

SCALE RATING.

Scaling Constituents. Parts per Million.		
More than	Not more than	Classification.
——	90	Good.
90	200	Fair.
200	430	Poor.
430	680	Bad.
680	——	Very bad.

The principal cause of foaming in boilers is usually an excess of dissolved substances, which increases the surface tension of the liquid, thereby reducing the readiness with which the steam bubbles can break. As alkali salts remain dissolved in the boiler water while the greater portion of the other substances is precipitated, the foaming tendency is commonly measured by the degree of concentration of the alkali salts in solution. The amount of alkali bases previously estimated multiplied by 2.7 gives a sufficiently accurate figure to represent the probable amount of sodium and potassium compounds. The result should be recorded only to the nearest ten parts and with but two significant figures.

FOAMING RATING.[2]

Foaming Constituents. Parts per Million.		
More than	Less than	Classification.
——	70	Very good.
70	150	Good.
150	250	Fair.
250	400	Bad.
400	——	Very bad.

[1] *Proc. Am. Ry. Eng. and Maintenance of Way Assoc.*, Vol. 5, 1904, p. 595.
[2] *Proc. Am. Ry. Eng. and Maintenance of Way Assoc.*, Vol. 9, 1908, p. 134.

Corrosion, or "pitting," is caused chiefly by the solvent action of acids on the iron of the boiler. Aside from free acids, which are rarely encountered in natural waters, acids liberated by deposition of magnesium as the hydrate are commonly believed to be the important cause of corrosion. It is believed that such radicles may pass into equilibrium with other bases in solution, displacing equivalent proportions of carbonates and bicarbonates, or they may decompose carbonates that have been precipitated as scale, or they may combine with the iron of the boiler. The certainty of these reactions is not known and can be expressed, even with the most complete analyses, only as a probability. If these acids exceed the amount required to decompose all the carbonates and bicarbonates corrosion is likely to occur; but if the amount of carbonates and bicarbonates equals or exceeds that required to satisfy both calcium and magnesium corrosion is not likely to occur. Intermediate conditions are uncertain. Formulas for expressing these relations can be deduced by adapting Stabler's scheme of computing corrosive tendencies.[1]

If $.033\,CO_3 + .016\,HCO_3$ equals or exceeds $.02\,H$ no corrosion is likely to occur.

If $.004\,H$ exceeds $.033\,CO_3 + .016\,HCO_3$ corrosion is likely to occur.

One fiftieth of the total hardness ($.02\,H$) is equivalent to the reacting value of calcium and magnesium, and H divided by 230 ($.004\,H$) is equivalent to the reacting value of magnesium on the assumption that $Ca = 6\,Mg$, an extreme ratio; $.033\,CO_3$ and $.016\,HCO_3$ represent respectively the reacting values of carbonates and bicarbonates, and the coefficients are obtained by dividing the valence of each radicle by its molecular weight. Corrosion is a very serious trouble and much tendency in that direction unfits a water for boiler use.

The value of a water for boiler use can therefore be judged by its scaling, foaming, and corroding ratings.

Classification for Irrigation.—The interpretation of water analyses in reference to irrigation has been so thoroughly treated

[1] *Eng. News,* Vol. 60, 1908, p. 355.

by Mr. Stabler, to whose article reference has been made, that discussion of it here is unnecessary. The deleterious effect of dissolved minerals in waters applied to lands is caused practically by alkalies, alkaline carbonates being most injurious and alkaline sulphates least injurious. Mr. Stabler's formulas are:

If $Na - .65\,Cl$ is zero or negative,

$$k = \frac{2{,}040}{Cl}.$$

If $Na - .65\,Cl$ is positive but not greater than $.48\,SO_4$,

$$k = \frac{6220}{Na + 2.6\,Cl}.$$

If $Na - .65\,Cl - .48\,SO_4$ is positive,

$$k = \frac{662}{Na - .33\,Cl - .43\,SO_4}.$$

The alkali coefficient (k), which is a measure of the tendency to damage, is defined as "the depth in inches of water which on evaporation would yield sufficient alkali to render a four-foot depth of soil injurious to the most sensitive crops." The waters may be classified by the following rating.

ALKALI RATING.

Value of k.		
Greater than	Less than	Classification.
18	——	Good.
6	18	Fair.
1.2	6	Poor.
——	1.2	Bad.

The value for alkalies previously computed may be substituted for Na in these equations. Values of k computed from field assays should be reported with not more than two significant figures and only to the nearest 10 when they exceed 30.

Interpretation in Respect to Domestic Use.—The field assay gives no information regarding possibility of pollution or presence of small amounts of poisonous, inorganic substances; there-

fore the data can not be said to permit classification of waters for domestic use. Field results, however, throw some light on this problem by showing the amounts of certain undesirable constituents. About 250 parts per million of the chloride radicle is perceptible to the taste, and though water containing an amount far greater than this can be drunk, increases become more and more objectionable till the water is nauseating and stimulates thirst instead of allaying it. About 400 parts of the sulphate radicle is perceptible to the taste. Though waters containing as much as 1,500 parts per million of sulphates are potable they are not refreshing and can not be used for cooking. Of the common substances in solution alkali carbonates are least acceptable to animals as well as to plants. Hardness as indicating the amounts of soap that must be used in washing assists in valuation. Yet standards of hardness are so purely local that general expression of them is not practicable. For instance, water with a hardness of 200 parts per million would be considered "very hard" in Vermont and "very soft" in Indiana. Individual adaptability and tolerance, which do not establish limits for the mineral ingredients of potable water, as well as lack of precise information make it worse than useless to offer any classification of the mineral ingredients in reference to domestic supply except to suggest that knowledge of the principal ingredients gives an idea of the type of water and the estimate of total solids an idea of the total content.

All the estimates in the laboratory analyses were made according to Stabler's formulas,[1] and those in the field assays by the formulas just outlined. Total solids were weighed in the laboratory after being dried for one hour at 180° C. None of the computed figures for total solids is far enough from the true value to cause misinterpretation except in assay no. 14, in which the error is due to an incorrect determination of sulphates. The great numerical differences in "alkali coefficient" and "foaming ingredients" are due to the fact that the methods of computation concentrate and magnify all errors of determination. Yet

[1] *Eng. News*, Vol. 60, 1908, p. 355; Vol. 64, 1910, p. 57.

TABLE II.

COMPARISON OF ESTIMATED VALUES.

(Parts per million.)

No.	Total Solids.		Alkali Coefficient.		Incrusting Ingredients.		Foaming Ingredients.		Probability of Corrosion.	
	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.
1	120	138	140	400	90	90	30	3	Non-cor.	Non-cor.
2	120	178	200	85	100	90	20	30	"	"
3	120	150	40	70	110	95	50	30	"	"
4	150	140	40	40	90	90	70	70	"	"
5	170	200	70	80	115	125	50	40	"	"
6	170	180	60	42	135	115	40	50	"	"
7	180	168	80	37	135	85	40	70	"	"
8	190	225	140	136	200	180	1	1	?	?
9	190	210	100	136	160	150	30	20	Non-cor.	Non-cor.
10	190	218	50	22	100	120	120	120	"	"
11	200	210	140	60	170	150	30	40	"	"
12	200	202	11	14	55	65	190	150	"	"
13	220	200	30	27	145	135	80	80	"	"
14	230	364	40	40	145	180	90	110	?	?
15	230	266	9	10	75	90	200	190	Non-cor.	Non-cor.
16	250	232	16	19	120	120	160	140	"	"
17	240	220	11	12	95	110	190	180	"	"
18	370	344	40	35	300	180	1	40	?	?
19	310	312	10	11	80	80	280	260	Non-cor.	Non-cor.
20	340	386	5	5.6	60	75	360	340	"	"
21	370	350	7	10	120	100	310	230	"	"
22	830	872	3	3.6	60	60	900	860	"	"
23	960	1,268	6	9	110	125	860	1,000	"	"
24	1,000	1,118	4	4.7	530	490	460	400	?	Corrosive.
25	1,500	1,702	19	20	840	600	360	290	Corrosive.	"
26	1,600	1,392	12	12	980	580	270	380	"	"
27	1,600	1,826	14	17	880	830	430	50	"	"
28	1,600	1,616	4	4.2	190	150	1,400	1,400	?	?
29	2,300	2,452	1	1.1	560	450	2,300	2,000	Non-cor.	Non-cor.
30	3,000	3,210	6	10	1,200	980	1,300	460	Corrosive.	Corrosive
31	3,800	3,930	.5	.6	90	60	4,500	4,200	Non-cor.	Non-cor.
32	6,800	7,489	.5	.5	1,900	2,590	5,000	4,200	Corrosive.	Corrosive

the limits of interpretation are such that these differences affect the interpretation of only one or two waters. The alkali coefficients in set no. 1, for example, are stated as 140 and 400 respectively, but as all waters with alkali coefficients exceeding 18 are considered good for irrigation, the numerical difference has no practical significance. In set no. 16 the difference in alkali coefficient throws one water from the "good" to the "fair" class, but the dividing point, 18, is so near the computed coefficients that the difference of classification is immaterial. Similar obser-

vations hold in reference to the foaming ingredients. In set no. 27 an obvious error in the field determination of total hardness causes a difference in foaming constituents, but not in classification of the water, which is very bad for boiler use on account of its other attributes. All except one of the estimates of incrusting ingredients based on field assays are near enough to make differences immaterial. One water that the laboratory analysis shows to be corrosive could not be classified in that respect by the field assay. In all other waters this tendency was uniformly estimated.

When the rating tables are applied to these numerical estimates and descriptive terms of classification are applied to the waters as in the following table, it is readily seen that the field assays supply the general information in respect to quality that is needed for practical description.

Additional evidence in support of these classifications is afforded by observed uses of the waters. Nos. 1, 5, 8, 9, and 13, all classed as good for irrigation, have been used without any trouble on garden stuff, vines, peach trees, and alfalfa. No. 25, though high in solids, is classed as good for irrigation, and it has been used for a year on several varieties of garden stuff. Nos. 12, 18, and 27, classed as fair, have been applied on alfalfa and wheat. All crops except alfalfa irrigated by no. 30 are said to have been unsuccessful. No. 22 is said to kill vegetation. No. 23, fair for irrigation and bad for boiler use, has been used on a loose soil for a few years to water lawns and shade trees; before being used in boilers it is purified in a preheater and by treatment with soda ash, and the scale produced even after treatment, though thin, is hard and tough. No. 3, used for feed water and for making beer, produces a soft sludge when a small amount of soda ash compound is added and there is no trouble from corrosion or foaming. No. 6 is used without trouble as feed water and in wine-making; the boilers are cleaned once a quarter and are blown every day. No. 14 is a locomotive supply. Nos. 29, 31, and 32, classed as bad for irrigation and very bad for boilers, are not used for anything. The waters not specifically mentioned are domestic or stock supplies.

TABLE III.

COMPARATIVE CLASSIFICATION OF WATERS.

No.	Mineral Contents.		Value for irrigation.		Value for Boiler Use.		General Character.	
	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.
1	Low.	Low.	Good.	Good.	Good.	Good.	Calcium carbonate.	Calcium carbonate.
2	"	"	"	"	"	"	" "	" "
3	"	"	"	"	Fair.	Fair.	" "	" "
4	"	"	"	"	Good.	Good.	Sodium carbonate.	Sodium carbonate.
5	Moderate.	Moderate.	"	"	Fair.	Fair.	Calcium carbonate.	Calcium carbonate.
6	"	"	"	"	"	"	" "	" "
7	"	"	"	"	"	Good.	" "	Sodium carbonate.
8	"	"	"	"	"	Fair.	" "	Calcium carbonate.
9	"	"	"	"	"	"	" "	" "
10	"	"	"	"	"	"	Sodium carbonate.	Sodium carbonate.
11	"	"	"	"	"	"	Calcium carbonate.	Calcium carbonate.
12	"	"	Fair.	Fair.	"	"	Sodium carbonate.	Sodium carbonate.
13	"	"	Good.	Good.	"	"	Calcium carbonate.	Calcium carbonate.
14	"	"	"	"	"	"	" "	Calcium sulphate.
15	"	"	Fair.	Fair.	"	"	Sodium carbonate.	Sodium carbonate.
16	"	"	"	Good.	"	"	" "	" "
17	"	"	"	Fair.	"	"	" "	" "
18	"	"	Good.	Good.	Poor.	Poor.	Calcium carbonate.	Calcium carbonate.
19	"	"	Fair.	Fair.	"	"	Sodium chloride.	Sodium chloride.
20	"	"	Poor.	Poor.	"	"	Sodium carbonate.	Sodium carbonate.
21	"	"	Fair.	Fair.	"	"	" "	" "
22	High.	High.	Poor.	Poor.	"	"	" "	" "
23	"	"	Fair.	Fair.	Bad.	Bad.	Sodium sulphate.	Sodium sulphate.
24	"	"	Poor.	Poor.	"	"	Sodium chloride.	Sodium chloride.
25	"	"	Good.	Good.	"	"	Calcium sulphate.	Calcium sulphate.
26	"	"	Fair.	Fair.	Very bad.	Very bad.	" "	" "
27	"	"	"	"	"	"	" "	" "
28	"	"	Poor.	Poor.	"	"	Sodium chloride.	Sodium chloride.
29	Very high.	Very high.	Bad.	Bad.			Sodium carbonate.	Sodium carbonate.
30	"	"	Fair.	Fair.	"	"	Calcium sulphate.	Calcium sulphate.
31	"	"	Bad.	Bad.	"	"	Sodium chloride.	Sodium chloride.
32	"	"	"	"	"	"	" "	" "

CONCLUSION.

It has been attempted to indicate the value of field assays to geologists and engineers by practical examples of their use, accuracy, interpretation, and the limitations to which they are subject. They offer means of classifying waters in a broad general way, but they can never compete with laboratory analyses when funds are available for doing a proper amount of detailed work. They enable the agricultural engineer to reject at once waters that are absolutely unfit for irrigation and to accept others that are evidently suitable; they also give some indication of the

precautions he must observe in using the waters. They enable the railroad chemist to reject at once waters unsuitable for boiler use and to accept without further examination waters that are perfectly good, and also thus to narrow down the number of samples that he must send to his laboratory for more careful examination. Ranchers can be warned to avoid, without experimenting on their stock, waters that should not be used for drinking on account of their mineral content. They enable geologists to trace the extent of underground formations and the distribution of underground waters by means of the composition peculiar to certain waters. Geologists can obtain by these methods valuable practical information regarding quality of water, general in character, but of an amount that they could not accumulate in so short a time or with so little expense in any other manner now known.

Mention of a few studies in connection with which the field methods have been employed shows how varied their application can be. Field assays were made in locating the best sources of boiler waters in Wabash and Des Moines River basins, and in both areas the conclusions from consideration of the assays were correct, so far as they could be checked by the limited number of complete analyses available; in the latter basin the influence of the gypsum deposits around Fort Dodge on the mineral content of the water of Des Moines River was traced entirely by the field methods. In Ohio and Rhode Island assays have been made for the purpose of tracing the pollution of surface waters by certain industrial wastes, and in New York for tracing the origin of spring waters. In Minnesota the first mapping of the quality of the surface waters was made from results of field assays, and the figures thus obtained were later verified by series of laboratory analyses. In Michigan Lane and Davis traced the extent of certain formations by testing with similar but cruder apparatus the mineral content of typical waters. In Kansas the normal range of mineralization was determined for the principal streams by detailed analysis of the chief surface waters, but the ultimate sources of the mineral matter were followed and located on the

tributaries by means of field assays. In Carson Sink, Nev., maps showing the distribution of salts in an area of 400 square miles were prepared and the limits of lands non-irrigible on account of the quality of available waters were fixed solely by field assays. Similar work has been performed in Lovelock's Valley in the same State. In San Joaquin Valley, California, by means of field assays, areas of water poor for irrigation and of water bad for boiler use or for domestic purposes have been located; the junction line of typical waters from the east and west sides of the valley has been sharply defined, and all the available waters have been classified. These instances of a few studies in which assay methods have been used indicate the variety of service for which they are available and show how useful they can be to the working field geologist.

HISTORICAL REVIEW OF THEORIES ADVANCED BY AMERICAN GEOLOGISTS TO ACCOUNT FOR THE ORIGIN AND ACCUMULATION OF OIL.[1]

MARIUS R. CAMPBELL.

INTRODUCTION.

Although petroleum as an earth product has been known for centuries, the modern development of the oil and gas industry as well as knowledge regarding the geologic relations of oil dates only from the completion of the Drake well at Titusville, Pa., August 28, 1859. To one familiar with the equipment of to-day, it is hard to realize the difficulties encountered in drilling this pioneer well and that at least one year was consumed in sinking to a depth of 69 feet. Out of this humble and crude beginning have grown the enormous oil and gas industries of the present time, industries that reach to the farthest corner of the globe and involve hundreds of millions of dollars.

At this time and place it seems fitting to attempt to sum up the progress that has been made in this country in the knowledge of the geologic relations of the pools and the ultimate origin of the oil. In the interval of fifty years since the drilling of the Drake well scores of fields have been discovered and thousands of wells have been drilled in the United States alone. Many of the ablest geologists of this country have given their attention to the problem, while a great number of men of lesser prominence but equally earnest in their endeavors to settle the question have been studying its various phases in the different fields.

Although petroleum is found in almost every country on the globe, the writer will confine his remarks to the progress that has been made in this country where the industry received its first great impulse and probably where more systematic prospecting has been done than in any other part of the globe.

[1] Published by permission of the Director of the United States Geological Survey. Presidential address delivered before the Geological Society of Washington.

It is extremely difficult, if not impossible, to determine what were the opinions of scientific men of more than fifty years ago regarding the geologic relations of the bitumens which for ages had been known to exude from the crust of the earth. The scientific literature of that period was meager and, so far as the writer is aware, little or nothing had been published regarding the geology of such substances, except possibly papers dealing with the kind and geologic age of the rock from which it was derived. This statement is not intended to convey the idea that these substances had not attracted attention, but the persons interested in them were mainly chemists who were engaged in studying their composition and speculating regarding their origin, whereas the question of their geologic relations and the reasons for their accumulation into pools does not seem to have been considered at all. Even after the drilling of the first well and the resultant wave of commercial excitement, little was written on this subject for twenty or twenty-five years.

This is peculiar and difficult to explain. Here was a new industry which was practically created during this interval and its formation was one of the most spectacular events in the history of mineral development in the world. Geologists must have been familiar with this great expansion and in part must have assisted in it, but the only records that are preserved are a few papers giving descriptions of new fields and discussions of the stratigraphy as exposed by the drill. It is possible that no definite opinions were reached during that period or that geologists may have been in the position of waiting to see what would be the outcome, unwilling to express their ideas, for fear they would not stand the test.

In considering this stage of development of the oil industry it must be remembered that there were no great geological organizations to take up the problem. The federal geologists were engaged in work in the Far West, to which they were restricted by law and also probably by taste, and Pennsylvania had no state organization to carry on this kind of work. The first geological survey of that state had passed out of existence and the second

had not yet been created. This left the petroleum problem to be solved only by private and individual effort.

APPALACHIAN OIL FIELDS.

During the period just mentioned of apparent inactivity among geologists regarding the scientific aspects of the oil problem certain ideas of great importance seem to have gained currency, but to whom the scientific world is indebted for their origin it is now impossible to say. Perhaps some of these originated with the operators themselves, but be that as it may they were in current use and so must be regarded as public property. Probably the most important of these ideas was regarding the character of the reservoir rock. On this subject geologists and operators of that day were divided into two camps, and the views of each were widely discussed and insisted upon by various members of both factions. Some supposed the oil to be contained in the interstices between the grains of sand composing the oil rock while others were equally certain that the oil occurred only in open fissures. Indeed in the first twenty years of exploration it seems probable that the latter view was most commonly held, as it offered an explanation that seemed entirely adequate to account for the phenomenon, whereas the theory of oil accumulating only in the pores of the rock seemed to tax the imagination beyond the limit of probability, and consequently was held only by a few men who could realize the possibilities of such an hypothesis.

In regard to the geologic or structural relations of oil, little seems to have been done during this period. Only two men seem to have felt the importance of this phase of the subject. These men were Dr. T. Sterry Hunt, of Canada, and Professor E. B. Andrews, of Marietta, O. Andrews from his field observations in the vicinity of Marietta noted that oil occurred along the Volcano anticline in West Virginia and Ohio and was not found in the flat-lying rocks on either side. On this account the anticline was long known as the "Oil Break." In November, 1861, Andrews published a paper entitled "Rock Oil, its Geologic Relations and Distribution,"[1] in which he described the geologic

[1] *American Jour. Sci.*, 2d Ser., Vol. 32, pp. 85–93, 1861.

structure of the anticline and the occurrence of oil, but he attributes its presence to reservoirs formed by fissures in the sandstone, induced during the process of folding. Fissures, he says, are more abundant on the anticline and hence the oil accumulates in that locality. In all his published papers on this subject Andrews adhered strongly to this theory and so far as the writer is aware did not in later years change his mind concerning it.

Hunt, on the other hand, seems from the first to have had a clear understanding of the character of the reservoir and of the effect that geologic structure may have had on the accumulation of oil, but, he had no opportunity to study the details as has been done by later geologists. To Hunt certainly belongs the credit of the first suggestion of what later became very prominent as the anticlinal theory. His first published statement is as follows:[1]

> These wells occur along the line of a low broad anticlinal axis which runs nearly east and west through the western peninsula of Canada, and brings to the surface in Enniskillen the shales and limestones of the Hamilton group, which are there covered with a few feet of clay. The oil doubtless rises from the Corniferous limestone, which as we have seen contains petroleum; this being lighter than the water, which permeates at the same time the porous strata, rises to the higher portion of the formation, which is the crest of the anticlinal axis, where the petroleum of a considerable area accumulates and slowly finds its way to the surface through vertical fissures in the overlying Hamilton shales, giving rise to the oil springs of the region.

From this paragraph it is clear that Hunt regarded the oil as contained in the pores of the sandstone and not in crevices, as seems to have been the common belief at that time. He also attributes its migration up the rise of the rocks towards the axis of the anticline to difference in the specific gravity of oil and water.

Although most of Hunt's researches on oil were devoted to its chemistry and origin he seems to have held to the view given above, although he appears to have been its only public advocate, for a number of years. In 1866 the Geological Survey of Canada

[1] "Notes on the History of Petroleum or Rock Oil," *Canadian Naturalist*, Vol. 6, pp. 241–255, August, 1861.

published a statement[1] regarding the structural relations of oil similar to that given above in a report of progress which bears only the name of Sir William E. Logan, but from the form of statement as well as from a later reference to this report by Hunt, it is apparent that he was its author and the only man in Canada or even in North America who expressed such views.

Alexander Winchell seems to have been the first to formulate the conditions necessary for an adequate reservoir as follows:[2]

> Where the shales are covered by an impervious layer, as of shale or plastic clay, the oil and the gas elaborated are retained in the rocks, filling cavities by driving the water out by elastic pressure, and saturating porous strata embraced in the formation, or intervening between it and the impervious cover above.

This appeared in the *American Journal of Science* in 1865, but was quoted from a private report which was published in 1864. The conditions necessary for a reservoir were more clearly stated in 1873 by Dr. John S. Newberry as follows:[3]

> This structure consists in a great mass of carbonaceous strata below, more or less disturbed and loosened, from which the oil is supplied in a constant and relatively copious flow; above this, strata of porous, jointed sandstone, serving as reservoirs where the constant product of oil and gas may accumulate for ages; still higher, argillaceous strata, impervious in their texture, and not capable of being opened by fissures, forming a tight cover which prevents their escape.

Although during the first fifteen years of the oil business many excellent ideas had been put forward, there was at the end of that period little unanimity among scientific men regarding the principles that controlled the circulation of oil through the rocks and its accumulation into pools.

The inauguration of the Second Geological Survey of Pennsylvania in 1874 offered an exceptional opportunity for the study of the various problems relating to the origin, mode of occurrence, and utilization of oil. J. P. Lesley, the energetic director,

[1] Canada Geol. Survey, 17th Report of Progress, p. 233, 1863–66.

[2] "On the Oil Formation in Michigan and Elsewhere," *Am. Jour. Sci.*, 2d Series, Vol. 39, 1865, p. 352.

[3] Geological Survey of Ohio, Vol. 1, 1873, p. 160.

seems to have fully appreciated this fact and he planned and carried out a series of admirable reports on the subject. John F. Carll, a practical oil man and a resident of Venango County, in which the famous Drake well was located, was selected to make special studies of natural gas and oil and the result is five volumes devoted almost entirely to this subject besides incidental discussions by Stevenson, White (I. C.), Platt (Franklin), Chance and Ashburner, in county reports.

Here was the greatest opportunity ever offered to determine the geologic relations of the oil pools, but one searches the reports in vain to find an adequate discussion of the problem. Apparently, most of the time of the geologists was given to collecting and studying the logs of wells and determining the stratigraphic positions of the oil sands, and while such studies are necessary and in this case were admirably done it may be questioned whether, except in a very broad regional way, the voluminous oil reports of the Second Survey were of any great practical value to the operators, desirous of opening new fields or extending the limits of those already discovered.

At this distance and with what seems to be the proper perspective one cannot but wonder why Lesley and his assistants were so wide of the mark in their scientific work and why some one of the able men engaged in that survey did not rise to the occasion and develop some rational theory to account for the presence of one of the greatest natural resources of the state. Carll, who must be regarded as the petroleum expert of that organization, scarcely mentions the subject of the relation of geologic structure to the accumulation of oil. His work was carried on mainly in the northern part of the state, and there he found the oil rocks dipping gently to the southwest but no mention is made nor does he seem to have considered the possibility of there being synclines and anticlines in the gently dipping strata. White and Platt discussed only the stratigraphic relations of the oil and did not, so far as the writer is aware, consider the possibility of there being other factors in the problem. Stevenson in his admirable reports on the southwestern

corner of the state considers to a certain extent the influence of anticlinal structure, but it is apparent that he gave it little weight as a controlling element, except to recognize that it was always accompanied by fissures in which the oil could accumulate. His most explicit statement regarding it is as follows:[1]

> Experience having shown in western Virginia and southwest Pennsylvania that oil could be procured in economical quantities only where there seems to have been some decided disturbance of the strata, those engaged in procuring this oil came to regard this disturbance as necessary to the original production of the oil itself. But a few considerations, I think, will suffice to show that the oil in no wise owes its origin to disturbances of strata, and that the only effect of the disturbance has been to provide reservoirs for the oil in the rock already oil-bearing.

That he refers to fissures in the rock is shown by another paragraph in the same report[2] regarding conditions on Dunkard Creek:

> They (the borings) give no evidence of faults or crushes. . . . No extensive crevices occur, and in boring the tools seldom drop more than two or three feet. At the same time crevices of small size are of frequent occurrence, and oil was obtained only when a crevice was struck. . . . The great frequency of these fissures can hardly be explained by supposing them to be the result of shrinkage; and it seems necessary, as well as in accordance with observed facts, to regard them as due to the action of some disturbing force exerted along the line, but without sufficient energy to produce permanent effects visible on the surface.

The disinclination of the geologists of the Second Survey to consider geologic structures as a possible condition affecting the accumulation of oil is possibly explained by the attitude of the Director, J. P. Lesley, expressed in 1880 in a preface to one of the oil reports:[3]

> The supposed connection of petroleum with anticlinal and synclinal axes, faults, crevices, cleavage planes, etc., is now a deservedly forgotten superstition. Geologists well acquainted with the oil regions never had the slightest faith in it, and it maintains its standing in the popular fancy only by being fostered by self-assuming experts who were not experienced geologists.

[1] Report K, pp. 394–5, 1875.
[2] Report K, pp. 393–4, 1875.
[3] Preface to report I 3, October, 1880, p. 16.

In 1885, at the Pittsburg meeting of the American Institute of Mining Engineers he voiced his opposition to the anticlinal theory as follows:[1]

> Quite recently the location of the anticlinal lines in the Pittsburg region has become a sort of popular mania, produced by a theory. The whole community interested in the subject of natural gas has been carried away by the theory. . . . And the theory to which I allude is the anticlinal theory of gas.
>
> It is impossible, . . . that any arrangement of water, oil and gas can occur in the deep oil rocks, such as occurs in a bottle. . . . It therefore seems to me irrational to assign any importance whatever to the extremely gentle anticlinals of the gas-oil region.

With this arbitrary dictum the head of the state organization apparently succeeded in preventing any of his associates from carrying on studies that would be likely to lead to a conclusion at variance with that given above and also from expressing in any way sympathy or agreement with such conclusions.

Following the lines of Andrew's and Hunt's investigations of the early days of the oil industry, Mr. F. W. Minshall, a practical oil man of Marietta, O., in 1878 began a detailed examination of the Volcano anticline or "Oil Break" of West Virginia apparently to determine what geologic conditions had resulted in the accumulation of oil along this fold. The results of his work published in a series of letters to the *State Journal* of Parkersburg during the summer of 1881, reached the people directly interested in the question, but were effectually buried from the scientific world. From a brief quotation given in Vol. 10 of the Tenth Census the writer learns that Minshall found that the crest of the anticline undulates and that oil is restricted to the summits of the local domes. He states: " . . . We may safely conclude that the productive oil territory of West Virginia must be confined to the summits of the anticlines or local rolls similar to the White Oak line." In this quotation he does not state clearly whether he follows Andrews in considering that the oil occurs only in fractures or Hunt in limiting it to the ordinary

[1] "Geology of the Pittsburg Region," *Trans. Am. Inst. Min. Eng.*, Vol. 14, pp. 654–655. 1885–6.

pores of the rock, but his recognition of several oil sands seems to imply that he took the latter view.

This carries the review in a brief imperfect way down to 1885 or twenty-six years after the drilling of the first oil well, without any serious attempt to solve the problem of what forces operate and what conditions control the movement of oil through the rocks and as a result the operators throughout the oil regions were looking for oil springs or other surface indications by which to determine the location of their wells or were "wild-catting" without any guide, trusting to luck to find a pool and when once found trusting again to the same blind luck in determining its extension into new territory.

Although Hunt as early as 1861 had stated in a general way the anticlinal or structural theory of the accumulation of oil and gas, and Hoffer[1] had in 1876 called attention to the fact that in Canada, Ohio and West Virginia, the greater quantity of the oil occurs on the anticlines, to Dr. I. C. White belongs the credit of formulating this theory, of working out many of its details, and of applying it in a practical way in locating new and undeveloped fields. White, in discussing[2] the introduction of this theory, states that it was not new at that time (1885), but that it had never been formulated in such terms as to be intelligible to the layman and hence of practical value. In making the investigations upon which this theory was founded, he was assisted and even prompted by Mr. William A. Earseman, an oil operator. White began this work in 1883 and was soon convinced that the theory would account for most of the facts observed in the Pennsylvania gas fields but he did not feel sufficient confidence in his theory to publish it until 1885.[3]

As there have been so many statements published recently concerning this theory it may be well to quote some of the most important parts so as to understand clearly what White meant by the anticlinal theory in its first inception.

[1] "Die Petroleumindustrie Nordamerika's."
[2] West Virginia Geol. Surv., Vol. A, pp. 48-64, 1904.
[3] "The Geology of Natural Gas," *Science*, Vol. 6, June 26, 1885.

After visiting all the great gas wells that have been struck in western Pennsylvania and West Virginia, and carefully examining the geological surroundings of each, I found that every one of them was situated either directly on or near the crown of an anticlinal axis, while wells that have been bored in the synclines on either side furnish little or no gas, but in many cases large quantities of salt water. . . . But while we can state with confidence that all great gas wells are found on the anticlinal axes, the converse of this is not true, namely, that great gas wells may be found on all anticlinals. In a theory of this kind, the limitations become quite as important as, or even more so, than the theory itself; and hence I have given considerable thought to this side of the question, having formulated them into three or four general rules (which include practically all the limitations known to me, up to the present time, that should be placed on the statement that large gas wells may be obtained on anticlinal folds), namely, (*a*) the arch in the rocks must be one of considerable magnitude; (*b*) a coarse or porous sandstone of considerable thickness or, if a fine-grained rock, one that would have extensive fissures, and thus in either case rendered capable of acting as a reservoir for the gas, must underlie the surface at a depth of several hundred feet (500 to 2,500 feet); (*c*) probably very few or none of the grand arches along the mountain ranges will be found holding gas in large quantity, since in such cases the disturbance of the stratification has been so profound that all the natural gas generated in the past would long ago have escaped into the air through fissures that traverse all of the beds; (*d*) another limitation might possibly be added, which would confine the areas where great gas flows may be obtained to those underlain by a considerable thickness of bituminous shale; (*e*) very fair gas walls may also be obtained for a considerable distance down the slope from the crests of the anticlinals, provided the dip be sufficiently rapid, and especially if it be irregular or interrupted with slight crumples. And even in regions where there are no well marked anticlinals if the dip is somewhat rapid and irregular, rather large gas wells may occasionally be found, if all other conditions are favorable.

Although it is not clearly stated that this theory applies only to saturated rocks, any one familiar with conditions in the oil fields of Pennsylvania and West Virginia would not question for a moment that such is the case. It seems probable that White had not at that time encountered dry rocks yielding oil and gas and consequently it did not occur to him to limit his theory to the conditions of saturated rocks, but it is evident from his reference to salt water in the synclines that he intended to apply it to

such a condition. Neither did White at first apply his theory to account for the accumulation of oil, but it is equally evident that he had this in mind and to him whatever theory would account for the accumulation of gas would also account for the accumulation of oil which differs from gas only in its physical condition and its specific gravity.

White's contribution to the subject of the mode of accumulation of oil and gas while covering only one phase of the problem still must be ranked as one of the greatest results achieved by modern geologists not only in its scientific bearing but also in its great practical value to the prospector and operator. For the first time since the discovery of oil and gas in commercial quantities the geologist could apply scientific rules to the solution of the problem and the extension of partially developed pools could be predicted with considerable certainty.

It is needless to say that the anticlinal theory did not meet with the general approval of geologists, as in most movements of this kind each advance is opposed by some worker who will not admit that his own theory is wrong and the theory proposed by another is correct. It was questioned by Chance and bitterly attacked by Ashburner, of the old Pennsylvania Survey, and even Lesley went out of his way in a paper presented in 1885 before the Mining Engineers at Pittsburg, as quoted on a previous page, in proclaiming it a fallacy, and also in his address at Ann Arbor, Mich., in the same year, as retiring president of the American Association for the Advancement of Science, to brand it as a failure. The greatest supporter of White and the anticlinal theory was Dr. Edward Orton, state geologist of Ohio, who soon demonstrated that this theory was applicable to the great oil fields of Ohio and his advocacy practically settled the question that when the conditions are similar to those postulated by White the anticlinal theory applies.

When gas and oil were discovered in quantity in northwestern Ohio in 1884 Orton set about with characteristic energy to determine the causes and conditions that attended its accumulation. In many respects he had an ideal field for his investigations. The

country is flat and accessible and railroad levels were available at almost every point at which a well could be located. Under these conditions Orton soon worked out the geologic structure with considerable accuracy and found that he had to deal not with many flexures, as is the case in Pennsylvania and West Virginia, but with one only and thus his problem was simplified to a considerable extent.

Orton's great work with regard to gas and oil seems to have been in seconding White in the demonstration of the adequacy of the anticlinal theory. In doing this, however, he found that certain modifications were essential in applying it to the Ohio fields. His most important addition was the recognition of "terrace" structure as favorable to the accumulation of oil. As stated by White the theory provided for the accumulation of oil and gas only in anticlinal structures. In Ohio Orton found that oil and gas has not only accumulated in the crowns of the arches but also in many places on the flanks of the fold where the dips are arrested for some distance forming a structural terrace. On this terrace the oil tends to accumulate on the outer edge if the oil is moving upward and on the inner edge if it is moving downward, and some of the great fields of the state are thus located. Orton attributed this idea of the influence of structural terraces to F. W. Minshall, but the present writer has searched Minshall's report on the Macksburg field in vain to find any reference to structural terraces or even a description of such a feature. It seems probable that the matter had been discussed by them and Orton with characteristic generosity gave Minshall credit for the original idea. Orton's first statement regarding structural terraces is as follows:[1]

> In the old fields and in the new alike, irregularities of dip, involving change of direction, suspension, or unusual increase, have been found connected with the large production of both oil and gas in every instance where careful examination has been made. The composition of the series involved is identical for many thousand square miles, but so long as uniformity of dip is maintained, there is no valuable accumulation. As soon,

[1] "Preliminary Report upon Petroleum and Inflammable Gas," Geol. Surv. of Ohio, p. 21, 1886.

however, as this uniformity is broken in upon, the valuable stocks of gas and oil came to light.

In a later report[1] he refers to it as a terrace in the following words:

> The structure referred to is associated with the arrest or suppression of the prevailing dip of the rocks for a given space and the establishment of a terrace or level bench in its place. If the series had lain level instead of being inclined at the slight angle which marks most of eastern Ohio, the movement to which the present terrace is due would have resulted in a low arch, but the uplifting force was too feeble to do more than counteract for a short space the normal dip by which the entire series is effected.

Terrace structure is very prominent in the Cincinnati arch and is probably responsible for most of the accumulation of oil in the Trenton limestone in the Ohio and Indiana fields.

With the able assistance of Orton it is now generally regarded that White proved the correctness of his anticlinal theory and thereafter he seems to have regarded the problem of the accumulation of oil and gas as forever settled and that the last word on this subject had been said. Up to the close of the century there was therefore little or no addition made to our knowledge of the method of oil accumulation even though in that interval White published two volumes of the Geological Survey of West Virginia, which dealt principally with the question of oil and gas. In these volumes he ably reviews his fight to establish the anticlinal theory without seeming to realize that the establishment of this theory was only a step and that many modifications would have to be made in adapting it to the conditions met with in the field.

The most recent development of ideas regarding the accumulation of oil and gas in the Appalachian region seems to have come largely, if not wholly, from geologists of the Federal Survey, who prior to this time had not been identified in any way with the investigation. In 1900 the writer with several assistants began a resurvey of western Pennsylvania, directing special

[1] "Geological Survey of Ohio," ECON. GEOL., Vol. 6, p. 94, 1888.

attention to the delineation and the study of geologic structure which had been almost entirely neglected by the previous surveys of that region. About the same time Mr. W. T. Griswold and M. J. Munn began similar work in eastern Ohio except that all of their determinations of altitude and position were accurately made and consequently their representation of the geologic structure was the most accurate and detailed that had ever been attempted. In summing up briefly the results obtained during the progress of this work the writer is at a loss to know to whom the credit should be given for many of the important ideas developed. In most cases these were discussed for months or years before they were put into print and frequently the man who first used them in a report was not the man who advanced the original idea, but the published record is the only one available so these ideas will be credited to the man who first used them in his printed report.

Although almost every worker in the oil and gas fields of southwest Pennsylvania had discovered that the anticlinal theory would not apply to dry rocks and that all of the lower sands are dry in that region Mr. L. H. Woolsey was the first to state it in an oil report, and this was merely incidental and without adequate discussion. He says:[1]

"If the sand holds much water, oil should occur high on the flank (of the anticline); if little water, low on the flank; if none, near the bottom of the syncline."

Mr. F. G. Clapp, working in the extreme southwestern corner of Pennsylvania, had to deal even more directly with dry rocks, than did Woolsey in the Smiths Ferry district. In Greene County and the southern portion of Washington County, Clapp found that most of the productive sands, especially the deeper ones, are almost universally dry and that the pools of oil do not follow the rules laid down in the anticlinal theory. His conclusions are as follows:[2]

[1] Geologic Atlas of the United States, Beaver Folio No. 134, 1905. Also the same statement occurs in Bull. 286, p. 81, 1906.

[2] Geologic Atlas of the United States, Folio No. 146, 1907.

Considerable doubt has been thrown on the anticlinal theory by oil and gas operators, on account of various apparent exceptions to its application. By most geologists the theory is now accepted, not, however, as indicating absolutely the limitations of the occurrence of oil and gas, but as expressing the general relations of their occurrence to geologic structure, such relations being subject to many modifying conditions. Some of the most important modifying conditions are (1) the presence or absence of salt water in a given region or in a given sand; (2) the continuity and shape of the anticlines—whether they are rising or pitching; (3) the porosity of the oil rock—that is, its capacity to hold oil; and, where the rocks are saturated, (4) the height of the water level.

Again he says:

Where salt water is absent the oil occurs more irregularly and its position is more affected by other conditions; it may lie along the synclinal axes or at many points scattered over the slopes of the fold.

In the study of these fields Clapp and Stone found that in synclines of dry rocks the oil is most irregularly distributed. At first they were puzzled to know how oil could be so widely distributed throughout dry rocks, but finally this was explained on the supposition that it might have accumulated during an early period of saturation and then have been disseminated. This is stated as follows:[1]

The structural position of the oil pools and the dryness of the rocks in Greene County suggest the hypothesis that the oil accumulated in pools after the formation of the rocks, while they were yet saturated with water, but that with the recession or disappearance of the water the oil moved by gravity back down the slope of the bed to its present position. Under these conditions the oil would be stopped in its downward progress by a reversed dip, by a dip of lower angle, or by increased density or thinning out of the reservoir rock.

In the opinion of the writer no more important discovery has been made regarding the accumulation of oil than that noted above, namely, the recognition of (1) that the conditions of accumulation are entirely different in saturated and unsaturated rocks; (2) that in saturated rocks the water level may be differ-

[1] Stone, Ralph W., and Clapp, F. G., "Oil and Gas Fields of Greene County, Pennsylvania," Bull. U. S. Geol. Surv., No. 304, p. 82, 1907.

ent in different basins in the same sand; (3) that the water level may not have been constant in past geologic time and that rocks which today are dry, previously may have been saturated; and (4) that under certain conditions the oil has moved up the slope, whereas under other conditions it has moved down the dip of the porous beds.

About this time Griswold and Munn discussed the problems of oil accumulation even more fully than Stone and Clapp and their conclusions were practically the same. With regard to unsaturated rocks they say:[1]

> In dry rocks the principal points of accumulation of oil will be at or near the bottom of the synclines or at the lowest point of the porous medium, or at any point where the slope of the rock is not sufficient to overcome the friction, such as structural terraces or benches.

Only one more quotation need be given along this line from one of the same authors:[2]

> The condition of saturation with water is not the same in different sands. Experience has shown that the older or lower beds in the Appalachian field contain a smaller area of completely saturated rock than the upper or younger sands. The lowest sands seem to be almost entirely dry, only the very lowest points in the center of a structural basin showing any considerable quantity of salt water.

Recently Mr. M. J. Munn has published several papers dealing with the question of circulation and accumulation of oil in the rocks in which he puts forward a number of new ideas and questions many of the old ones that are generally considered to be well established. At this time it is impossible to say whether Mr. Munn is correct and the old ideas will have to be abandoned or materially modified or whether his new ideas themselves will be relegated by future workers to the scrap heap upon which many of the theories of former times have found a resting place.

Before leaving the consideration of the Appalachian oil fields

[1] Griswold, W. T., and Munn, M. J., "Geology of Oil and Gas Fields in Steubenville, Burgettstown and Claysville Quadrangles, Ohio, West Virginia and Pennsylvania," Bull. U. S. Geol. Surv., No. 318, p. 15, 1907.

[2] Griswold, W. T., "Berea Oil Sand in Flushing Quadrangle, Ohio," Bull. U. S. Geol. Surv., No. 346, pp. 20–21, 1908.

perhaps one other point should be mentioned, not that it necessarily concerns that province alone but that it seems to be a possible factor in the migration of oil in many fields. This is the facility with which oil will diffuse through dry fine-grained material. This was brought to public attention in 1897[1] and in 1903[2] by David T. Day who conducted experiments to see if by the use of dry fuller's earth he could not separate crude oil into various fractions. He succeeded in his experiments and from this he argued that the various grades of oil found in any one field were derived from the same source and that the lightest grades had migrated farthest from the original place of origin, but his contention has not been granted by geologists and its real value as a contribution to the science is yet to be determined.

The circulation of oil through shale may be explained satisfactorily by the hypothesis mentioned above, but the final result would be dissemination rather than accumulation, unless there is present some other condition that restricts diffusion and produces concentration. This limiting condition is found in moisture in the fine-grained rock, but to whom should be given the credit of the discovery the writer does not know. Day doubtless observed it, but failed to state it in any of his publications.

The writer has dwelt at considerable length on the results obtained in the Appalachian and eastern fields for the reason that a greater number of geologists have been engaged in the study of those fields and also that the fields have been known for a much longer period of time than those of other parts of the country. Also for the reason that the principles that have been developed in the Appalachian field are applicable to other fields in Paleozoic or equally hard rocks. Hence the generalizations regarding the Appalachian field are true of the Ohio, Indiana and Illinois fields as well as the Mid-continent of Kansas and Oklahoma and also of many fields in the Mesozoic rocks of the Rocky Mountain region.

[1] *Amer. Phil. Soc. Proc.*, Vol. 36, No. 154, February 5, 1897.
[2] *Science*, New Series, Vol. 17, 1902.

TEXAS SALINE OIL FIELDS.

The history of oil development in this country has been full of surprises to those who held preconceived notions that all oil fields were constructed on the same general plan. As a rule, operators and drillers as well as geologists have gone from the Pennsylvania fields to those of the West and South and, in most cases, they have attempted to develop the new fields along the lines laid down in the old. Frequently this has resulted disastrously and the operator and geologist have been forced to recognize that different conditions prevail from those with which they were familiar and that the new field presented new and unsolved problems. This is nowhere better illustrated than in the development of the saline oil fields of the gulf coast.

In the general wave of oil exploration and development that swept over the country from the Appalachian region when that was in the height of its production, oil was found at Corsicana, Texas, in flat-lying rocks that were similar in geologic structure to the rocks of the mid-continent field of Kansas, and it seems to have been generally assumed that there were no new problems in the oil fields of the gulf coast. Captain A. F. Lucas, however, was not of this opinion. For years he had been exploring the salt beds of Louisiana and he appears to have been the first to fully appreciate the dome structure of such deposits and to have been imbued with the idea that they contained not only salt and sulphur but also petroleum. His famous gusher on Spindletop near Beumont, Tex., struck oil January 19, 1901, and fully demonstrated the correctness of his theory, although this was not generally accepted by the geologists best acquainted with the field. Some endeavored to convince the public that the conditions at Spindletop were similar to those at Corsicana and that the pool would be found to have a considerable lateral extent, but the oil drillers soon disproved this idea and showed that oil was practically limited to the dome and the small mound which constitutes its topographic expression.

In attempting to sum up existing knowledge of the Texas saline fields the first and most important question seems to be,

Are these pools associated with extraordinary structures? For many of them the answer must certainly be yes. The next theoretically important question is regarding the origin of such domes and their relation to faults or other lines of weakness in the earth's crust. The whole discussion of this subject has been so recent that it is difficult to obtain the proper perspective by which to judge the merits of the case. As is generally well known the nucleus of the domes are salt or salt, sulphur and dolomite and against the side of this mass the strata are upturned forming an ideal catchment area for the oil. The salt extends indefinitely downward, the deepest wells having in most cases failed to penetrate to the bottom of the mass.

So far as the writer is aware, only three or four theories have been advanced to account for the origin of these apparently anomalous structures, which are worthy of consideration.

Mr. Robert T. Hill in October 1902[1] notes the following as phenomena accompanying the saline oil:

1. The oil is closely associated with the mounds occurring on their slopes or summits.
2. The mounds are usually anticlinal or quaquaversal in structure.
3. Most of the chemical phenomena of the Lucas group occur in all these mounds in varying proportions.
4. In some localities hot water has been struck below the oil.
5. In the original Lucas well the oil itself is hot.

At first Hill was inclined to the belief that the oil at Spindletop occurred in nearly horizontal sedimentary rocks but later he says:

Since studying the phenomena of the Beaumont field the writer has gradually developed another hypothesis, namely, that these salt bodies are the result of secondary replacement in the strata through the agency of the ascending circulation of saturated briny waters.

His hypothesis is as follows:

The oil and salt pockets of the Texas coastal plain are probably not indigenous to the strata in which they are found, but are the resultant

[1] "Beaumont Oil Field," *Journ. of the Franklin Inst.*, Vol. 154, pp. 143–156, 225–238, 263–281, 1902.

products of columns of hot saline waters which have ascended under hydrostatic pressure, at points along lines of structural weakness, through thousands of feet of shale, sand, and marine littoral sediments of the Coastal Plain section, through which oil and sand are disseminated in more or less minute quantities. The oil, with sulphur, may have been floated upward on these waters and the salt and dolomite may have been crystallized from the saturated solution.

The channels of these ascending waters may have been in places of structural weakness such as fissures which probably at one time continued to the surface, but may have been sealed by the deposition of the later overlapping strata now capping the oil pools. Such features, when occurring under general anticlines, may explain the collection of oil beneath the surface in pools.

Hayes and Kennedy in commenting[1] on Hill's hypothesis say:

Many facts may be adduced in support of this hypothesis, although it must be admitted that it presents some serious difficulties. The mode of accumulation of the enormous masses of rock salt which occur in the Louisiana salt islands, in Damon Mound, in High Island, and also in Spindletop, has never been satisfactorily explained.

Hayes and Kennedy refrained from advocating any theory, but in discussing the subject of structure they state:[2]

Its (crustal movement) most striking characteristic appears to be the concentration of differential effect at certain points which forms the mounds of uplift, of which Spindletop may be regarded as the type.

Although this statement is very guarded and expresses little, still it seems to imply that they looked upon the dome structure of the saline mounds as due to regional earth movements, a theory which does not appear to have been held by any other recent workers in this region and which seems to be totally inadequate to account for the facts.

After a study of the igneous intrusions and faults of central Texas Mr. Lee Hager came to the conclusion in 1904 that the saline mounds of the coastal plain are due to laccoliths which in

[1] "Oil Fields of the Texas-Louisiana Gulf Coastal Plain," Bull. U. S. Geol. Surv. No. 212, pp. 143–144, 1903.

[2] *Op. cit.*, p. 145.

no place appear at the surface. He states his hypothesis as follows:[1]

> The movement which resulted in the great Balconies fault or a similar movement in late Tertiary times extended to the rock-sheets below the present coastal plain accompanied by igneous activity as in the vicinity of the fault itself. Fault-blocks resulted, thrust up by intrusive masses of igneous material in the form of laccoliths at great depth. Owing to the nature of the Tertiary deposits, yielding clays, marls, and quicksands, the faulting proper was confined to the deep-lying indurated lower Cretaceous and Carboniferous rocks. In the unconsolidated materials of the overlying Tertiary and upper Cretaceous a dome-like structure resulted, due to the vertical thrust of the fault blocks pushed by the intrusive masses in the form of laccoliths.

With great candor he admits that the weak point of his theory is that while calling into play igneous activity to account for the formation of the domes no trace of such action is observable at the surface in any part of this region and consequently he has to assume that it acted uniformly at such a depth that it gave no surface indication. This, of course, is possible but certainly not probable, and it is doubtful if the hypothesis will have any standing with future geologists who are familiar with the field.

Apparently the man who has given most thought to this problem and who has put forward the best hypothesis to account for these structures is Mr. Gilbert D. Harris, state geologist of Louisiana. Harris approached the petroleum problem through a study of the saline mounds of Louisiana without however at the time realizing that this study might lead to the solution of the problem of the saline oil fields of that state and Texas.

With the organization of the survey in 1898 Mr. A. C. Veatch, Harris' assistant, began a critical study of the various salt deposits of the state. He soon came to the conclusion that probably all of these were associated with dome or anticlinal structure. His results were published in Harris' reports of 1899 and 1902.

Although as early as 1899 Harris appears to have become con-

[1] "The Mounds of the Southern Oil Fields," *Eng. and Min. Jour.*, Vol. 78, pp. 137–139, 180–183, July 28 and August 4, 1904.

vinced of the dome structure of these salines, the first mention the writer can find regarding his idea of the method of formation is in his report for 1907:[1]

> The longer we study these peculiar structures the more convinced are we that although they may be located along lines of weakness, faults or fractured anticlines, they are not to any great extent due to tangential, mountain-making forces, nor to volcanic upheavals, nor igneous plugs, as has recently been suggested, but to the slowly-acting, little understood, concretion-forming forces as well as the power of crystallization.

In his more complete discussion of the subject he says:[2]

> We believe there is practical unanimity now amongst geologists regarding the secondary nature of the salt masses so frequently met with in Louisiana and Texas domes. In nearly every case, we believe, the various writers quoted above have come to this conclusion independently and in spite of very strong early inclination toward a normal or 'salt-pan' origin. We believe all will admit that water has been the dissolving and transporting agent. The main difficulties in the whole matter have been (1) how can rising columns of water be made to precipitate their salt, even though saturated, and (2), what is the force that lifts up a certain hundred or thousand feet of superficial strata in limited areas almost never two miles across. The remarkable circular form of the domes and their quaquaversal dips and the extent of their proven vertical movements in comparison with their diameters—these two are troublesome factors.
>
> In brief we answer (1) precipitation is due to decrease in temperature; and (2) the requisite uplifting force is amply accounted for by the power of growing crystals.

Although this hypothesis may be considered somewhat radical and in that respect open to question, still it seems to one entirely unprejudiced in the matter, the only competent and logical hypothesis put forward to account for these saline structures and therefore the most important contribution to our knowledge of this field.

It therefore appears to the writer that Lucas and Harris are the men who have contributed most to our knowledge of the saline oil fields of the gulf coast, but while they have added greatly

[1] Geological Survey of Louisiana, Bull. No. 5, pp. 8–9, 1907.
[2] Geological Survey of Louisiana, Bull. No. 7, pp. 59–83, 1908.

to the subject there are many problems connected with these fields that are yet unsolved, as for instance, the mode of origin of the oil and the place from which it came. It must be admitted, however, that Hager's volcanic hypothesis has derived considerable support from the recent discovery in the gulf coastal plain of Mexico of igneous plugs accompanied by many of the phenomena observed in the Texas fields.

From a purely scientific standpoint the saline fields of the gulf coast are the most unique and interesting in this country and they probably abound with many unsolved, if not unsolvable problems.

CALIFORNIA OIL FIELDS.

Naturally, many of the traditions and scientific theories of the Appalachian oil fields were carried to California when prospecting was begun in that state some thirty-five years ago, but so far as structural conditions are concerned little similarity could be observed between the nearly flat-lying conformable beds of the eastern fields with their fairly regular oil sands and the greatly folded, badly fractured and generally unconformable rocks of the Pacific Coast.

Although the State Mining Bureau of California began a study of oil about 1890 its efforts were concentrated on descriptions of the various fields and individual wells and little headway was made in determining the geologic relations of the oil pools during the first twenty-five or thirty years. In 1899 Mr. A. S. Cooper, then state mineralogist, in his report dealing with the origin of California oil, considers briefly the geologic relations, bringing out certain facts which more recent work has completely verified. In the Appalachian region, as also in all other oil fields, in hard rocks, it has long been recognized that faults provide means of escape for both oil and gas and that even closely appressed folds are not likely to retain either of these substances. Cooper found that in the soft Tertiary rocks of California, faults instead of affording avenues of escape for the oil, in many places seal themselves and act as barriers. His statement is as follows:[1]

[1] "The Genesis of Petroleum and Asphaltum in California," California State Mining Bureau, Bull. No. 16, p. 21, December, 1899.

> If an oil-bearing bed ascending to the north be interrupted by an east and west fault the further ascent of the oil northward will be arrested and then an abundant supply of oil may be obtained by boring on the south side of the fault. . . .
>
> Selvage frequently occupies the line of faults generally caused by the movement of the two sides of the fault on each other which have ground up the materials of the rock, forming a sheet of matter impervious to the flow of oil or water. . . .

It seems probable that the sealing of rocks along a fault line is due rather to the amount of clay contained in the rocks which under extreme pressure becomes plastic and is spread out evenly over the cut edges of the country rock, but be that as it may, the recent history of the oil fields of California seems to indicate that in places faults do constitute barriers to the progress of the oil.

Cooper also seems to have realized, even before that idea was thought of in the eastern fields, that the water level in the rocks may have changed during geologic time, for he says:[1]

> When the underlying water which supports the oil is released by the uplift of a formation above the permanent water by orogenic movements the water leaves the formation and the oil drains into the void formerly occupied by the water. . . .

The men who have contributed most to a knowledge of the conditions prevailing in the California oil fields are Ralph Arnold, Robert Anderson and Harry R. Johnson. While the principal part of their work has been of such a recent date that there has been little opportunity for its verification, still the results have been of inestimable value to the practical oil man and presumably the principles upon which it is based are sound or at least mainly correct.

In attempting to sum up the really important scientific results obtained by Arnold, Anderson and Johnson, one is handicapped by the lack of discussion in their reports of the causes and conditions which have led to the formation of oil pools. This in part is doubtless due to the great complexity of the problem, to the natural conservatism of the authors, and to the demand on the part of the general public for information on specific fields without regard to the principles that have governed their formation.

[1] *Op. cit.*, p. 54.

The scientific contributions of these authors may be summed up as follows: *Cause of migration of oil through the rocks.* In view of the lack of evidence regarding the presence of water and its effect as a medium for the transference of oil, they arrive at the tentative conclusion that "This migratory faculty may be ascribed entirely to the presence of the associated gas which would cause the oil to fill every crevice offering a point of escape or a point of lodgement."[1]

On this hypothesis the oil would move in the line of least resistance which in almost all cases would be upward toward a surface outlet. In another report they refer to diffusion as a possible mode of movement of the oil:[2]

> This cause (of the migration of oil from its source) . . . (is) the tendency of oil to migrate by diffusion through certain media such as dry shales.

These do not necessarily interfere with one another and both may have affected the migration of the oil. The same may be said of water, if it can be shown that water is contained in quantity in any of the oil-bearing sands.

Conditions affecting migration.—In most fields water is ruled out as an active cause of movement of the oil and consequently the modifying conditions of structure and water level so important in the saturated and folded sands of the eastern fields have little or no effect here. The conclusion is that ". . . The condition of the rocks is the chief factor that controls the matter of where the oil is stored most abundantly." If this idea is correct the oil may pass more readily through coarse porous sandstone, fractured denser rocks, and may even migrate from one formation to another where two sandy beds are in unconformable contact.

Barriers against migration are usually formed of dense impervious rocks, but in certain places.

[1] The quotations given in this summation are taken from "Geology and Oil Resources of the Santa Maria District, California," Bull. U. S. Geol. Survey 322, 1907, pp. 73–74.

[2] "Preliminary Report on the Coalinga Oil District, California," Bull. U. S. Geol. Surv., No. 357, p. 113, 1908.

The residual or heavy hydrocarbons that are left upon evaporation of the lighter substances originally in the contained petroleum, seal the outcrops and hinder or prevent the escape of the oil from below.[1]

In the East such a condition is hardly possible but with the heavy oils of California it is of comparatively common occurrence.

3. *Reservoirs.*—In the Appalachian oil field the reservoirs holding the oil are sandstone and consequently the term "sand" has come into common use in this sense. In the California fields, many of the sandstones are oil-bearing, but Arnold and Anderson "Have come to the conclusion that in this region many of the 'oil sands,' so called, are not true sands, but zones of fractured shale or flint offering interspaces in which the oil can gather."[2]

4. *Relation of Oil Pools to Structure.*—In many of the fields of this state anticlines are marked by accumulations of oil. This has led to the belief by many that the anticlinal theory applies here as well as to the eastern fields. The explanation given by the authors mentioned above is that since it is uncertain whether or not the rocks of the California fields are saturated with water it is doubtful if the anticlinal theory applies and, to use their own language, "Large accumulations in anticlines may be accounted for primarily by the cavities offered by the strata along upward folds, and secondarily by the presence of less pervious beds arching over such folds and affording favorable conditions for the confinement of oil and gas tending to escape."

The geologic conditions in the California fields are so complicated that it is extremely difficult to formulate general laws regarding the migration or occurrence of oil and gas, but the important point seems to be the recognition that in such soft and slightly indurated rocks the conditions in many cases are directly contrary to those pertaining to more brittle rocks. Also the element of time seems to enter into the question for since the deposition of Tertiary rocks, sufficient time has not elapsed for the

[1] "Geology and Oil Resources of the Coalinga District, California," Bull. U. S. Geol. Survey No. 398, 1910, p. 186.

[2] *Loc. cit.*

escape of all of the hydrocarbons even in zones of considerable faulting and disturbance whereas in the Paleozoic rocks of the East the time has been so great that even the minutest fracture has presented ample opportunity for the escape of practically all of the hydrocarbons that were ever contained in the rock. By comparison of the two fields the oil sands in California are found to be less continuous, water conditions more uncertain, and the migration of oil through the rocks has been effected by so many modifying conditions that prediction of the result is extremely hazardous. Another point of difference between the East and the West is the presence in the latter locality of many angular unconformities which afford opportunity for the accumulation of oil and asphalt or for the migration of these substances from one formation to another and in places for the escape of the lighter hydrocarbons.

Owing to the complicated conditions it is doubtful if the laws governing the movement of the oil and the full effect of local conditions will ever be thoroughly understood.

COLORADO FIELDS.

Many small oil fields have been discovered in the Rocky Mountain region, but in most cases the geologic relations are the same as they are in the Appalachian region and so far as the writer is aware none of them presents exceptional or anomalous features except the Florence field of Colorado. Many eminent geologists have examined this field during the past twenty years but no one has offered a satisfactory explanation of the occurrence of oil in the basin-shaped depression which marks this field. Recently the field was studied by Mr. Chester W. Washburne, who as the result of this work offers the most rational explanation that has as yet appeared.

The Florence oil pool occupies a synclinal basin of Pierre shale lying just east of Cañon City. According to Washburne the wells are drilled in shale throughout their entire depth. Previous writers have assumed that there must be some porous beds that act as reservoirs despite the fact that no such beds are known in

outcrop and there is no constancy in the oil-bearing zone which extends throughout a thickness of fully 2500 feet.

Washburne's conclusions are somewhat unique, therefore liberal quotations will be made from his report. Regarding the range of the oil-bearing beds he says:[1]

> The upper surface of the productive zone is in places roughly parallel to the dip of the beds, but the upper surface of the zone in which traces and unprofitable amounts of oil and gas are found is in general nearly horizontal lying from 750 to 1,000 feet deep. The highest traces of oil and gas are reported at about this depth for the entire distance across the field, notwithstanding the fact that the Pierre shale descends 1,600 feet in that distance.
>
> The oil does not follow any bed or series of beds in the shale. As shown by the outcrop, the oil zone does not contain any sandstone or other porous beds capable of acting as reservoirs. The oil lies in joints and fissures. This statement is made without reservation, because the writer believes that it is fully justified by considerations which cannot be presented fully in this brief paper. The evidence consists of (*a*) observations on the correspondence in direction of the major joints observable in the rocks at the surface with the alignment of wells which have interfered with each other; (*b*) the fact that many wells have been drilled within a few feet of each other without encountering oil at the same depth; (*c*) the fact that gas struck in a shallow well often immediately ruins an adjacent well several hundred feet deeper by tapping the source of pressure; (*d*) the fact that many wells drain adjacent wells that are very much shallower; (*e*) the indications of vertical connection between the oil bodies shown by the marked increase in maximum pressure with depth; and (*f*) the dissimilar pressures in adjacent wells of the same depth.
>
> Corroborative evidence is furnished by the drillers, who report "crevices" in most of the wells. . . . In numerous . . . cases, . . . large quantities of water have been poured into a well without moistening the shale sufficiently to enable drilling to proceed, and the conclusion of the drillers that the water has been used up in filling a crevice is probably correct. Less certain are some other observations, such as the reported dropping of the tools as much as 20 feet beyond the distance drilled. . . . In this connection the following report of the United Oil Company's well no. 402, is interesting. "Bad crevices were found at 2,300 feet and the bailer was lost in one of these large crevices, but it did not interfere with

[1] "The Florence Oil Field, Colorado," Bull. U. S. Geol. Surv. No. 381, pp. 521–522, 1910.

the drilling, as the crevice was large enough to allow the bailer to be driven into it without interfering with the work."

Much additional evidence on the presence of fissures and the part they play in furnishing reservoirs for the oil is presented by Washburne but space and time will not permit of its presentation here.

With regard to the agencies which have caused segregation of the oil he writes as follows:[1]

> The concentration of the oil has probably been brought about by water, which is able to shove the oil before it on account of its greater capillary pressure, due to greater surface tension. . . . The oil is hemmed in above by the ground water and below by artesian water in the Timpas limestone and subjacent sandstone of the Carlile. The ground water supersaturates the shale for a distance of 300 to 500 feet from the surface.

Washburne's general conclusion seems to be that in the Florence field geologic structure has had little or no influence on the movement or the accumulation of oil. The oil is present mostly in open fissures and it has been forced into them and held in its present position by water on the same principle that damp fuller's earth serves as an impassable barrier to the oil.

This view certainly does not correspond with those of previous workers in this field and time may show that it is erroneous but in the opinion of the writer it is well supported by facts and probably in the years to come it may be regarded as the only tenable hypothesis.

ORIGIN.

The limits of this paper will not permit a review of all of the theories put forward during the last fifty years to account for the origin of petroleum and other hydrocarbons in the crust of the earth. In fact it is questionable whether such a review is worth making except to show that the workers, both geologists and chemists, have been actively endeavoring to solve the problem but most hypotheses are mere speculations and while they are interesting no direct proof of their applicability has been adduced.

[1] *Op. cit.*, pp. 523–524.

As is well known there are two main groups of these hypotheses, one ascribing an organic origin and the other an inorganic origin to the oil. In most cases geologists have subscribed to the theory of organic origin but their reasons for so doing are generally the absence of evidence of igneous activity, and the great mass of sediments in oil fields. While in a measure these reasons satisfy the holders of the hypothesis, still many have looked in vain for unmistakable proofs that oil has been derived from animal or vegetable matter. Fortunately, there is one place in this country where it has been possible practically to solve the question of origin and since this is such a great exception and so important of itself the writer will be pardoned if he goes rather fully into a description of the conditions. The region in question is California and the conclusions given here are the results of the work of Messrs. Arnold, Anderson and Johnson, whose reports have already been quoted in reference to these fields.

The studies of these geologists have shown that without much doubt foraminiferal and diatomaceous shale is the source of the California oil. In the fields on the west side of the Coast ranges the diatomaceous shale is carried in the Monterey (middle Miocene) shale and much the greater part of the oil in these fields occurs in that formation or in other formations which are in contact with or in close proximity to that formation. On the east side of the coast ranges in the San Joaquin Valley the Monterey is absent in some fields but other formations carry diatoms or foraminifera and in each case the oil is found only in these or closely associated formations.

In the Santa Maria oil field, the largest on the west side of the Coast ranges, the Monterey shale, according to Arnold and Anderson, can be separated into two divisions each of which is about 2,600 feet thick. The lower division contains some diatomaceous layers but the upper division is mainly composed of such material. they describe it as follows:[1]

> The infusorial earth, . . . of which the upper division of the Monterey is chiefly composed, . . . occurs in inexhaustible quantities. . . .

[1] "Geology and Oil Resources of the Santa Maria Oil District," Bull. U. S. Geol. Surv., No. 322, pp. 38-39, 1907.

The composition of the Monterey shale is of especial interest. One is able to see on examining the soft unaltered variety with a hand lens, or sometimes even with the naked eye, that it is full of small round dots ranging, to speak roughly, from 0.1 mm. to 1 mm. in diameter. These are the skeletons of minute marine organisms called diatoms. They are a low order of plants or algae having a framework of silica. They are locally so closely packed together that they seem to form the bulk of the deposit.

Aside from the diatoms the rocks of the Monterey contain remains of minute Foraminifera, which have calcareous frames, and Radiolaria, which secrete silica to form the tests.

In regard to the origin of the oil of this field these authors say:[1]

There is no doubt that the petroleum in the Santa Maria district is indigenous to the Monterey shale. Bitumen is a characteristic part of that formation throughout its wide extent over an area covering hundreds of square miles, and there is no other formation but the Eocene shales in which it is characteristic, or in which it occurs in appreciable quantity except locally, although there are numerous formations which would be capable of storing oil if any had originated in them. Moreover, the bituminous Monterey shale of the Coast ranges does not occur consistently above or below any one formation from which the oil could have been derived. It lies unconformably upon ancient metamorphic rocks; granite and other igneous rocks; Jurassic, Cretaceous, or early Tertiary sediments: or conformably over lower Miocene beds, according to local conditions; and it is either not covered by later deposits or is buried by sediments of various ages, in different places.

The decision is therefore unavoidable that some ingredients of the Monterey shale gave rise to the oil. . . .

The writers are strongly of the belief that the petroleum was derived largely from the minute organisms, especially the plant organisms (diatoms) which are present in such abundance in these shales.

They go on to say that there may be some question as to whether the oil was derived from the diatoms or from the foraminifera and radiolaria. In fact, there are several points strongly in favor of the animal origin, but these authors conclude with this statement:[2]

The general conclusion is that in the Santa Maria district the organic material in the Monterey shale that may have acted as the source of the oil was without doubt adequate in amount for the production of the vast

[1] *Op. cit.*, pp. 109–110.
[2] *Op. cit.*, p. 113.

quantity of petroleum now present, and that the forms included in greatest abundance, the diatoms, were the chief source, although animals and perhaps other plants also contributed largely.

On the east side of the coast ranges the formations have different characteristics and consequently different formations are regarded as the source of the oil. In the McKittrick-Sunset region the Monterey and the overlying Santa Margarita formation bear diatoms and they are regarded as having been the original source of the oil, but there is some doubt about the identity of the Santa Margarita and it is possible that this may be found to be equivalent to the upper part of the Monterey shale in the Santa Maria field. It is significant in view of the conditions in the Coalinga field that in the McKittrick-Sunset region the Tejon (Eocene) and Knoxville-Chico (Cretaceous) formations are not diatomaceous and no evidence has been found pointing even in a general way to these formations as a source of oil or gas. The conclusions regarding conditions in these fields are as follows:[1]

The organic matter in the Monterey shale is believed to be the source of at least a part of the oil in the McKittrick-Sunset region; its presence or that of the Santa Margarita (?) is therefore believed to be necessary for the accumulation of petroleum in this territory. Most of the hydrocarbon content has migrated to other formations, and entered the Vaqueros below or the McKittrick above, so that as a reservoir the Monterey is not important.

In the Coalinga field, farther north, the Monterey shale is absent and the Tejon and the upper part of the Knoxville-Chico are regarded as the source of the oil. Arnold and Anderson make the following statement concerning it:[2]

The oils of the Coalinga district are believed to have been derived from two different sources, namely, the organic shales forming the uppermost member of the Chico (Upper Cretaceous) and those described as the upper portion of the Tejon (Eocene). It is believed that the oil originated from the organic matter, both vegetable and animal, once con-

[1] Arnold, Ralph and Johnson, Harry R., "Preliminary Report on the McKittrick-Sunset Oil Region, California," Bull. U. S. Geol. Survey No. 406, 1910, p. 62.

[2] "Geology and Oil Resources of the Coalinga District, California," Bull. U. S. Geol. Surv., No. 398, p. 188, 1910.

tained in these beds. The shales are composed in large part of the tests of foraminifers and diatoms, and a smaller number of other organisms, in such abundance as fully to warrant the assumption that the animal and vegetable material that must have been contained in them when deposited was adequate for furnishing a quantity of hydrocarbons and other compounds more than equivalent to the quantity of petroleum found in this field.

Although both shales have contributed to the supply of oil in the Coalinga field the Tejon is regarded by Arnold and Anderson as the more important:[1]

> . . . because the uppermost member of the Cretaceous is limited to a small area in the northern part of the district we must look to some other source for the oil occurring in the Eocene and higher. Furthermore, the petroleum of the purple shale member of the Cretaceous is of a very different character from that obtained from the later beds, . . . The Cretaceous oil is greenish or brownish in color, of light gravity, and contains paraffin, a high percentage of naphtha, and a very low percentage of asphaltum. The other oil of the district is distinctly an asphalt oil and is lacking in paraffin. It is therefore evident that there are two distinct oils in the Coalinga district, to which different ages and origins are to be ascribed.

Thus it appears that the source of the oil is different in the different fields, depending upon the amount of diatomaceous and foraminiferal material in the formations. On the west side of the coast ranges the Monterey shale is the principal formation containing such material and it is the source of most of the oil. On the east side of the ranges the Monterey is the source of oil only where it is diatomaceous, but other formations partake of this character and, wherever they do, they also are regarded as the sources of some of the oil.

From this relationship between the diatom-bearing formations on the two sides of the coast ranges it seems to be apparent that these organisms were the ultimate sources of oil as claimed by Arnold, Anderson and Johnson. If it be granted that they have proven their case this will stand out as one region in which it has been possible to make a positive determination and these authors will have the distinction of being the first to do more than theorize regarding the organic origin of oil.

[1] *Loc. cit.*

RECENTLY DISCOVERED WOLFRAMITE DEPOSITS IN NEW BRUNSWICK.

T. L. Walker.

For nearly fifty years it has been known that certain quartz veins near the confluence of the South West Miramichi and Burnt Hill Brook, in the heart of New Brunswick, carry small quantities of molybdenite. Many geologists have visited this locality and in their reports refer to the presence of molybdenite. In September, 1910, the writer had occasion, on behalf of the Mines Branch, Ottawa, to examine the molybdenite deposits and incidentally discovered that Wolframite occurs in almost all of the veins. These deposits, which were of very doubtful value so far as molybdenite is concerned, attain a new and possibly real importance on account of the wolframite which they carry.

Geologically the region is extremely simple. Great batholites of granite have invaded and metamorphosed slate which is supposed to be of Cambro-Silurian age. Some distance from the granite contact the slate of the sedimentary series is almost black and quite cleavable. Near the contact however the slate becomes more massive like many typical contact products. A microscopic examination shows no corderite or andalusite.

The slates near the contact have been fissured and quartz veins have been formed. The quartz is practically free from accessory minerals other than the molybdenite and wolframite. Occasionally the quartz shows drusy structure and is quite vitreous, a very hungry looking material from the gold miner's point of view. In width the veins vary from a few inches to about two feet. They appear to owe their existence to the action of the granite from which the materials for the filling of the fissures—quartz molybdenite and wolframite—were probably derived.

The accompanying sketch map illustrates the geology of the region and indicates the river and railroad system of the district.

The wolframite forms large crystals scattered through the quartz veins with a tendency to aggregation near the borders. Some of the crystals are quite large, attaining nearly half a pound in weight. The mineral is black and lustrous with one prominent cleavage. Its specific gravity is 7.20—in short it is ordinary coarsely crystallized wolframite.

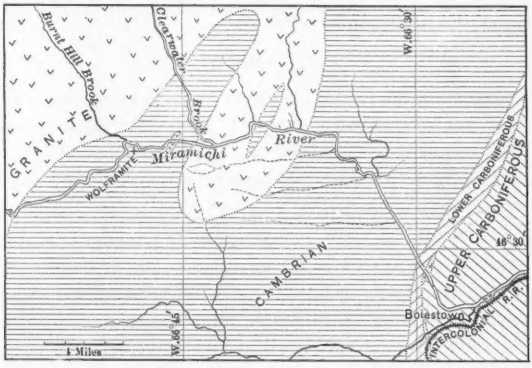


FIG. 56. Sketch Map of the new Wolframite region in New Brunswick.

The following analysis shows the presence of a considerable proportion of manganese, so that this wolframite differs in this respect from that mined so extensively in Boulder County, Col., which is almost pure iron tungstate:

	Per Cent.
FeO	16.90
MnO	8.37
WO_3	74.43
Total	99.70

The above analysis corresponds closely to the formula $2FeWO_4 \cdot MnWO_4$.

The region is difficult to reach, as it is not crossed by ordinary wagon roads and is some distance from the nearest railway. There are practically no roads except such as are available only

during the winter. The means of approach is by canoe on the Miramichi River from Boiestown, a good day's journey. Since the discovery of the wolframite deposits some work has been expended on the building of roads, construction of cabins and in the development of the deposits.

It is probable that this discovery of wolframite will be followed by a search in the surrounding region by prospectors for other deposits of the same kind.

THE RELATION OF BORNITE AND CHALCOCITE IN THE COPPER ORES OF THE VIRGILINA DISTRICT OF NORTH CAROLINA AND VIRGINIA.[1]

FRANCIS BAKER LANEY.

INTRODUCTION.

The copper ores of the Virgilina District consist almost wholly of bornite and chalcocite. The level of ground water is from 50 to 75 feet below the surface and the zone of secondary alterations does not appear to extend below 250 feet. The important mines of the district are from 350 to 500 feet deep and the ore from the deepest levels contain almost as much chalcocite as bornite. If a specimen from the upper levels of almost any of these mines be examined in detail it will be found to consist of the two minerals in such relations that no hesitancy is felt in pronouncing much of the chalcocite secondary and more recent than the bornite. If, however, a specimen be taken from the deeper levels the two minerals are seen to be so intricately intergrown that no other conclusion than that they are genetically contemporaneous seems possible. These facts have led some observers, notably L. C. Graton,[2] to suppose that chalcocite occurs in these mines as a primary mineral. Chalcocite has been almost universally regarded as a mineral of secondary origin, *i. e.*, derived from some leaner copper-bearing sulphide. Its manner of occurrence as heretofore observed left little doubt as to its secondary nature and there grew up a belief that the mineral is always secondary. The chalcocite of the Virgilina District therefore appeared to offer an exception to the generally accepted conclusion, and with the hope of throwing some light upon the genesis of this mineral

[1] Published with the permission of the State Geologists of North Carolina and Virginia.

[2] U. S. Geol. Survey, "Min. Res.," 1907, Pt. I., p. 620.

an extended microscopical examination of these ores was undertaken.

The field work upon which this investigation is based was done while the writer was employed by the Geological Surveys of North Carolina and Virginia, and a detailed report on the geology of the district is now being prepared. The U. S. National Museum furnished a metallographic microscope and equipped it with an improved lighting device especially for this work, and the photomicrographs illustrating the paper were made in the photographic laboratory of the museum by Thomas W. Smillie.

The specimens herein described are the property of the U. S. National Museum.

GEOGRAPHY AND GEOLOGY.

Before entering upon a description of the ores a brief sketch of the geology of the district will be given.

Location.—The Virgilina copper district is located near the eastern border of the Piedmont Plateau in Person and Granville counties, N. C., and Halifax and Charlotte counties, Va., each state including approximately one half of the ore-bearing area. It takes its name from the village of Virgilina, a station on the Southern Railway situated on the state line near the center of the district, and about 160 miles west of Norfolk and 45 miles east of Danville. The most important ore deposits occur on two approximately parallel flat-topped, though somewhat conspicuous, ridges which trend from 15 to 20° east of north, and which have very gradual slopes. The maximum elevation is at Virgilina, 540 feet above sea level. The relief is not pronounced, varying from about 300 feet up to the maximum above stated, but the country is decidedly hilly. Rainfall is rather heavy, especially during the winter and spring, and streams are numerous.

Geology.—The majority of the rocks of the district are highly schistose, and are popularly known as slates. They are of two distinct types—greenstone schists, and quartzose sericitic schists or gneisses. Into these schistose rocks have been intruded large masses of granite, and less important bodies of more basic mate-

rial, probably gabbro. Also here and there throughout the area occur small diabase dikes. The intrusive rocks are not schistose, but are closely jointed.

The Schists.—A close examination of the schists reveals their true character—a great series of volcano-sedimentary rocks of two types—a basic rock, andesite, and one highly acid in character, a quartz porphyry. Of the andesite there are three facies—porphyritic, amygdaloidal and tuffaceous, and of the quartz porphyry only two—porphyritic and tuffaceous. Closely associated with the greenstone schists and grading directly into them, are heavy beds of highly schistose greenish rocks differing from the tuffaceous portions of the andesite only in that they contain varying amounts of land waste intermixed with the basic volcanic material. These range from fairly well-marked sandstone and fine conglomerate on the one hand to typical andesitic tuffs entirely free from terrigenous material on the other. The relative position of these two phases of the greenstone indicates that at the beginning of the volcanic activity there was a period when the volcanic material was not equal to the land waste, and thus were deposited beds of sandstone and conglomerate with only a small amount of volcanic ash. As the activity increased, the amount of land material grew proportionately less and less, until at the time of maximum vulcanism it became nothing, and the normal volcanic beds were formed. As this activity began to diminish, the former conditions began to reassert themselves, and the beds deposited consisted to a greater or less extent of land waste. The andesitic tuff passes by regular gradation into the sandy and conglomerate rock, so that in the field, even where exposures are the best, it is not possible to draw a sharp boundary line between the two.

The following is a somewhat idealized cross-section through the middle of the district at right angles to the schistosity. This section is approximately that exposed along the Southern Railway from a point about ten miles west to about eight miles east of Virgilina.

It is possible that the sandy beds may have been formed from the rapid erosion of unconsolidated volcanic ash beds as well as by the commingling of similar material with land waste at the time of eruption. Thus in either case it is clear that with an increase of the volcanic material the resulting rock would more nearly approach the true basic tuffs, while with a decrease of this it would approximate more nearly a normal sediment—a conglomerate, sandstone, or shale as the case might be.

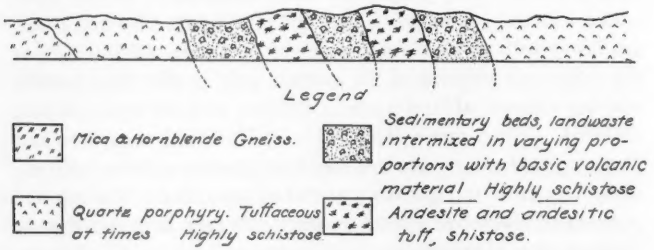

Legend
Mica & Hornblende Gneiss.
Sedimentary beds, landwaste intermixed in varying proportions with basic volcanic material Highly schistose
Quartz porphyry. Tuffaceous at times Highly schistose
Andesite and andesitic tuff, schistose.

FIG. 57. Cross section of Virgilina district at right angles to strike of schistosity. Approximately along Southern Railway.

The andesite and the andesitic tuff, especially the former, are the most massive of the older rocks of the region. The andesite is of three types, porphyritic, amygdaloidal and tuffaceous, all of which are mashed and decidedly schistose. The amygdaloidal phase is not abundant, and is usually so highly metamorphosed that it is easily confused with the tuffaceous phase. All the ore deposits thus far developed, and in fact all the prospects as far as known at present, with a very few exceptions, are located in the andesite or the andesitic tuff.

The quartz porphyry is, for the most part, especially on the western side of the area, a typical rock of its kind, but much mashed and highly schistose. The phenocrysts are largely of feldspar, with a variable and usually an inferior amount of quartz. The basal and the upper, and at times other portions of this rock, are to a greater or less extent tuffaceous. This is

especially true of the eastern area, where by far the greater portion is probably a very fine tuff. No workable ore deposits have been found in this rock.

The age of these rocks is not known; they have generally been regarded as pre-Cambrian. They appear to be somewhat similar to tuffaceous rocks intimately associated with the slate deposits lying northeast of the Virgilina district. These slates have recently been described by Watson[1] and Powell and shown to be early Paleozoic. It is believed that further study may determine the volcano-sedimentary rocks of this district to be of the same age.

Granite.—This is the youngest intrusive rock of the region except the diabase dikes, and is also the most important. Three prominent areas of it are included within the district, one in the southwest corner near Mill Creek Post Office, N. C., and another in the east-central portion at and surrounding Buffalo Lithia Springs, and the third and largest one, northwest of Redoak Post Office, Va. This area of granite extends almost across the region of volcano-sedimentary rocks and cuts out the ore-bearing horizon for a distance of four or five miles. It is apparently massive, and therefore shows nothing of the prominent schistosity of the other rocks. In all the occurrences it is a rather coarsely granular, highly quartzose rock, and in places, especially at Buffalo Lithia Springs, it is decidedly porphyritic. Like all the other granites of the southeastern United States, it contains a large amount of plagioclase in proportion to the orthoclase, and shows well its quartz-monzonitic character. This rock is of special interest since all the field evidence obtainable points toward the conclusion that it is the source of the ores, and that they and the veins are closely connected genetically with its intrusion. In this relation it is further considered in the paragraphs relating to the origin of the ores.

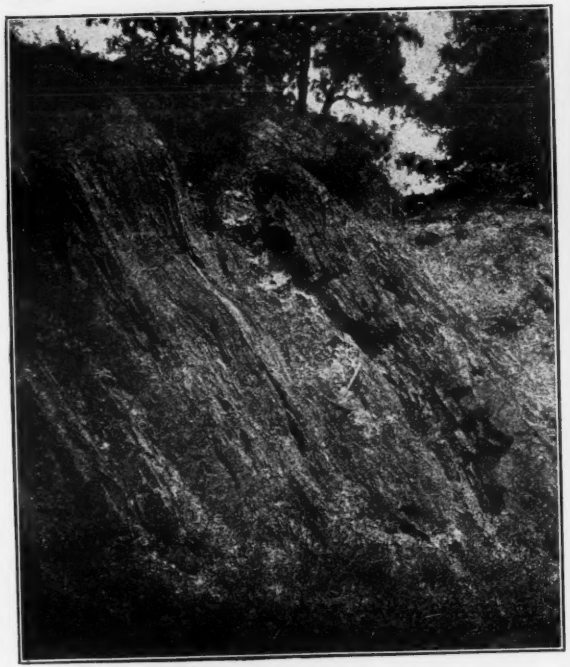
Structure.—From the cross-section above given, what the writer considers a probable interpretation of the structure of the district is readily seen, a closely compressed syncline, the axis of

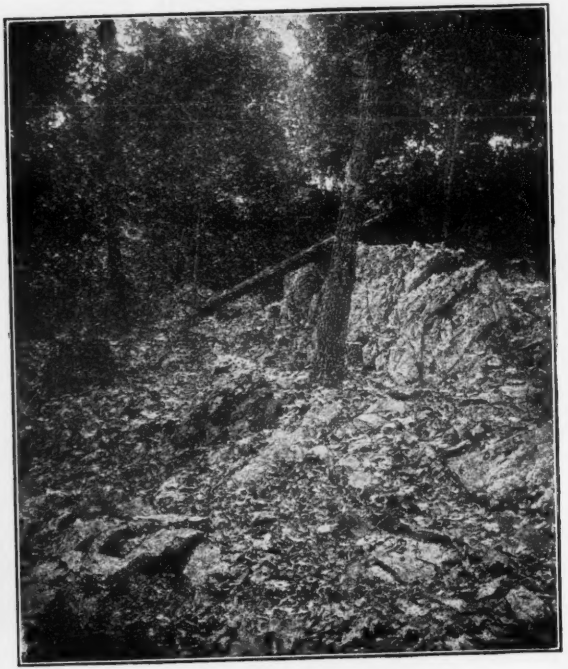
[1] Thos. L. Watson and S. L. Powell, "Fossil Evidence of the Age of the Virginia Piedmont Slates," *Amer. Journ. Sci.*, ser. 4, Vol. 31, 1911, pp. 33–44.

which has a strike of from 10 to 30° east of north, and which is inclined so that it has approximately the same dip as the schistosity—from 70 to 80° toward the southeast. It is believed that at the beginning of the formation of the series there was a great outpouring of acid lava,—the quartz porphyry, upon the mica and hornblende gneiss as a basement. This was followed by a period of quiescence, marking the beginning of the outpouring of the basic lava—the andesite. During this time the regular agencies of erosion were active, and the results were the beds of land-waste intermixed with basic volcanic ash. The vulcanism increased and there followed the great beds of andesite and andesitic tuff. Finally the activity decreased and a period similar to that at the beginning of the basic activity followed, and during this time the upper beds of sandy tuff were formed. This marked the close of the volcanic activity as far as any record in the rock goes. Following this the beds were intricately folded, much mashed, and the present schistosity largely developed. This was followed, probably after a long period, by the intrusion, first of the gabbro, later of the granite, and then, as phenomena concomitant with the coming in of the granite, the fracturing of the greenstone schists and the formation of the veins and the development of the ores.

VEINS AND ORES.

Veins.—The veins are composed dominantly of quartz with locally a considerable amount of epidote and calcite (see Pl. II.). In width they vary from small stringers not more than a few inches up to 15 or 20 feet. They always have well-defined walls and are probably true fissure veins. As is always the case with such veins, these present many irregularities, most prominent of which are the numerous pinches and swells, both horizontally and vertically. In places they are reduced to little more than a mere stringer of quartz between two well-marked walls, while again they may locally swell out to several times their average thickness. In length they range from a few hundred yards to four or even five miles, and in many instances may be traced these distances by actual outcrop or by abundant quartz débris in the

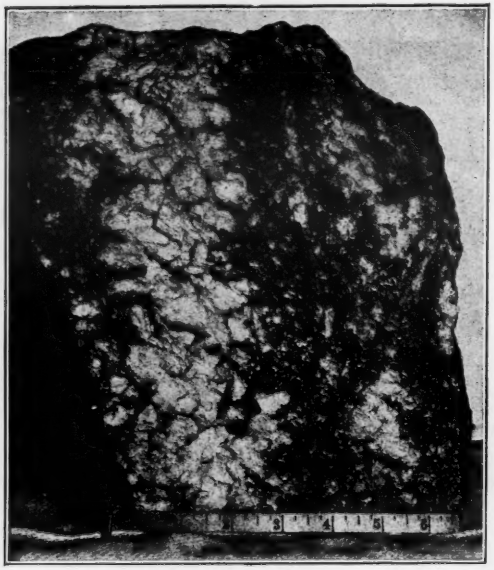




TYPICAL VEINS.

FIG. 1. Exposed in railroad cut near Christie, Va. The irregularities here shown are exhibited by nearly every vein that has been opened in the district.

FIG. 2. Outcropping of a large but barren quartz vein near High Hill Mine. Few of the vein outcrops are as prominent as this one.



BORNITE AND CHALCOCITE IN QUARTZ GANGUE. WALL MINE.

FIG. 1. Photograph of a specimen from the Wall mine showing relation of ore and quartz. The vein was "split" at the point where this specimen was taken and the piece here figured represents the entire width of one portion of the vein. Dark areas = ore. White areas = quartz.

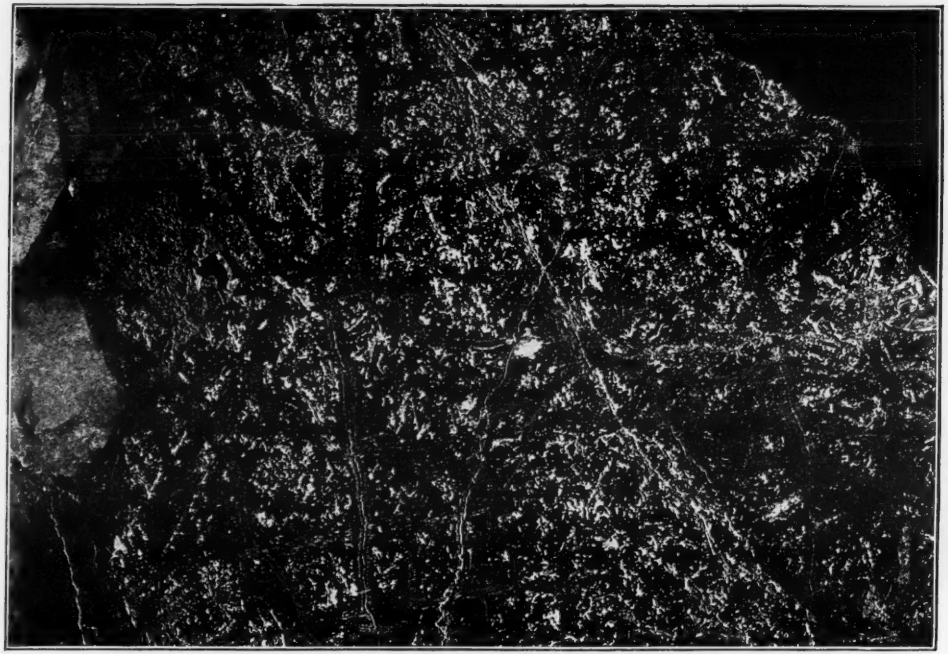
FIG. 2. Tracing made from a polished surface of a specimen from the Wall mine showing the relation of the ore to the quartz. Natural size. Black = ore, chalcocite and bornite. White = quartz. The relationship here shown is typical of all the mines in the district. The ore and gangue appear to be contemporaneous.

soil. Vertically they are also continuous, and aside from the irregularities in width they are as well defined in the bottom of the deepest shafts as at the surface. The size of the vein and the prominence of the outcrop form no criteria as to the richness of the mineralization. Often the richest ore bodies have been found under a very insignificant outcrop, and as often the strongest exposure at the surface is barren or very lean. The average strike of the veins is more northerly than the schistosity of rocks in which they occur, and while in places they follow the schistosity for short distances their average strike intersects it at acute angles. The fractures in which the veins have formed are therefore regarded as having been made subsequent to the development of the schistosity in the country rock. The ore is not evenly distributed throughout the veins, but is concentrated locally into definite ore shoots. These present the usual irregularities and as a rule appear to have a slight southerly pitch in the vein.

Ores.—Though apparently preferring the quartz, the ore is so intimately associated with all the gangue material as to make it almost certain that all were deposited contemporaneously (see Pl. III.). The copper-bearing minerals are bornite and chalcocite, with the oxidized products derived from them. Chalcopyrite is present in such small and varying amounts that unless careful search is made, it will not be found at all, and it is apparently no more abundant in one portion of a mine than in another. Certainly there is no increase with depth in the amount of this mineral. In fact the mine which shows it most abundantly is only about 150 feet deep, and here it was as abundant in the first sulphides encountered as in those in the bottom of the shaft. In two of the deepest mines—the Holloway, 450 feet in depth, and the Durgy, about 400 feet—it is so rare that one can hardly find it.

Chalcocite occurs in two very distinct relations with the bornite; secondary to and filling fractures in the bornite, and intergrown sometimes clearly crystallographically, with it. Bornite is the most important mineral in all the mines in the district except the Holloway, in which it is subordinate to chalcocite. It appears, too, from even a casual observation of the ores that there

has been considerable shattering since their original deposition. This is especially prominent in the ore from the Seaboard mine, which furnishes the purest bornite in the district. In the fractures in the bornite from this mine, be they ever so minute, are developed veinlets of chalcocite, which penetrate the bornite in all directions, and vary in size from the finest line, often not visible to the unaided eye, but perfectly clear under the microscope (Pl. VI., Fig. 1) up to areas a quarter of an inch in diameter (see Pls. IV. and V.). In the center of many of these chalcocite-filled fractures are films of quartz which evidently mark the original fracture in which the chalcocite began to develop, thus showing that at the beginning of, or prior to the development of the chalcocite, there were solutions carrying considerable quartz. In the interior of some of the largest quartz veinlets thus formed there occur particles of chalcocite so related to each other as to indicate a growth of the quartz since the beginning of the deposition of the secondary chalcocite (see Pl. V.). Also in a few instances the vein of chalcocite when deeply etched presents a kind of spongy skeleton of quartz appearing as if quartz and chalcocite were deposited simultaneously. The boundary between these veinlets of chalcocite and the bornite is exceedingly irregular, usually presenting a somewhat feathery outline, though always perfectly distinct and clear-cut. There is absolutely no gradation of one into the other. There is certainly a growth of the chalcocite, but how it takes place is not made clear by the microscopic study of the veinlets. It appears, however, that it takes place at the periphery of the material already deposited, but the chemistry of the process has not been worked out. Where fractures of two periods are present, both are often filled with chalcocite, that in the more recent fractures cutting across the veinlets in the older ones. Fractures also occur in the intergrown chalcocite and bornite, and in such instances the secondary veinlets cut across both the primary chalcocite and the bornite. The relation of the two minerals to each other in the case in hand leaves no doubt as to the secondary nature of the chalcocite. This type of chalcocite, as far as observations have extended, is con-



SECONDARY CHALCOCITE IN FRACTURES IN BORNITE. SEABOARD MINE.

Secondary chalcocite in bornite. × 10. Seaboard mine. This specimen shows a mass of bornite penetrated in all directions by a mesh or network of chalcocite which has formed in minute fractures in the bornite. It is typical of all the secondary chalcocite studied, the only difference being the stage of development. This one is farther advanced than any of the others. The white line in the center of many of the chalcocite veinlets is quartz. Running diagonally across the specimen is a recent fracture which cuts bornite and the older veins of chalcocite. In this chalcocite is also seen to be developing.

FIG. 1. Secondary chalcocite in bornite. ×40. Seaboard mine. Similar in all respects to section shown in Plate V., Fig. 1, only the development of chalcocite is farther advanced. The same feathery line of contact between the two minerals is evident. In the center of the chalcocite areas are seen films of quartz which apparently mark the original fracture in which the chalcocite developed.

FIG. 2. Secondary chalcocite in bornite. ×40. Seaboard mine. Similar to Fig. 1, but shows more clearly the relation of the chalcocite to the bornite. In one of the fractures in the bornite there is seen a stringer of quartz, the dark area running vertically through the section. On each side of the quartz, between it and the bornite, there is a considerable development of chalcocite.

FIG. 1. Secondary chalcocite in bronite. × 40. Seaboard mine. Irregular lines = chalcocite. Other portion of section = bornite. This specimen represents an incipient stage of the development of the secondary chalcocite in minute fractures in bornite. The little lines of chalcocite are well defined, but present an irregular or "feathery" line of contact with the bornite.

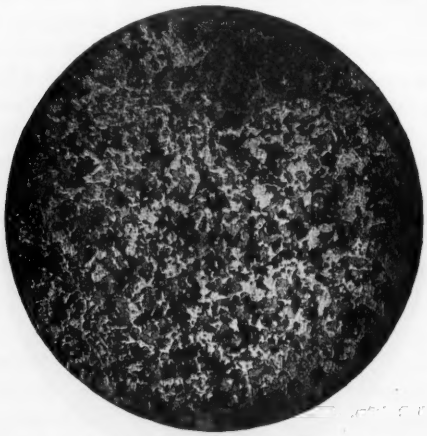


FIG. 2. Intergrowth of bornite and chalcocite. × 40. 266 foot level, Blue Wing mine. Dark areas = bornite. Lighter areas = chalcocite. There does not appear to be any marked crystallographic relationship between the two minerals in this section as in those shown in Plate VI. The appearance is that of a spongy mass of bornite merged and intergrown with another similar mass of chalcocite.

FIG. 1. Intergrowth of bornite and chalcocite. × 40. Wall mine. Dark areas = bornite. Lighter areas = chalcocite. A typical example of crystallographic intergrowth of bornite and chalcocite. Such intergrowths are believed to form only at the eutectic point of a solution and are strong evidence that the two minerals were deposited contemporaneously.

FIG. 2. Crystallographic intergrowth of bornite and chalcocite. × 220. Wall mine. Dark areas = bornite. Lighter areas = chalcocite. This figure represents an area of the finely intergrown portion of the section shown in Fig. 1, highly magnified, and shows that the relationship of the two minerals is a typical crystallographic intergrowth.

fined to the upper portions of the veins and was not found in sections of ore from the deeper mines. It was found, however, in the upper portions of all mines from which sections were examined, and in many instances a single section would show excellent examples of both types of chalcocite (see Pl. VII., Fig. 1).

The other type of ore is entirely different. Both minerals are present in every section examined, sometimes the bornite predominating, and at others the chalcocite. They are intimately associated with each other, but each has its own definite boundaries, cleavage, and other physical properties, with absolutely no indications that one is secondary to or derived from the other. In a number of sections the chalcocite predominated over the bornite, and in such instances the indications seemed to be that the bornite was the first to crystallize. It occurs in irregular areas, sometimes separated and again connected, lying in a larger area of chalcocite. In other instances the two are present in approximately equal amounts, and there is nothing to indicate that one is older than the other. In other occurrences, as in the ore from the Blue Wing mine, the two minerals are present as small areas or grains and in approximately equal proportions. In these sections the appearance is as if a sponge of bornite while growing had been merged with another similar sponge of chalcocite, the association being so intimate and so complex that there is no way of accounting for it except on the basis of contemporaneous deposition (see Pl. VI., Fig. 2). In the case of the sections in which the bornite appears to have been formed earlier than the chalcocite, it seems as though when the ores were being deposited, the solutions were first saturated, as it were, for bornite, and this mineral began to crystallize out, the iron possibly being the determining factor. This continued until by a reduction of the bornite molecules in the solution, the eutectic point for both bornite and chalcocite was reached, and these two minerals crystallized out simultaneously, and in many places solidified as crystallographic intergrowths. The chalcocite is rather coarsely crystalline, and the etch figures show that the larger areas are

made up of numerous interlocking grains, which stand out distinctly and have no definite crystallographic relation to each other. The cleavage, as brought out by the etching, is apparently in two directions at right angles to each other, one more prominent than the other, one possibly prismatic and the other basal.

The crystallographic intergrowths are the most interesting and also the most conclusive as to the contemporaneous deposition of the two minerals. These are by no means rare, having been found more or less perfectly developed in ore from all the mines except the Seaboard. At a magnification of 40 diameters these areas resemble very closely the intergrowths of quartz and feldspar in a micropegmatite. At the highest magnification used, 220 diameters, this resemblance is even more pronounced. In these intergrowths the minerals present perfectly sharp and clear-cut boundaries, with absolutely no indication of gradation of one into the other—boundaries just as sharp as between any minerals in an igneous rock (see Pl. VII.). When an area of such intergrowth was etched deeply enough to bring out the two cleavages distinctly (Pl. VIII., Fig. 1) the chalcocite proved to be a single grain or crystal, the cleavage lines of which could be seen extending from one side of the grain to the other, interrupted here and there by the filaments of bornite. This type of texture is regarded as proof that the minerals crystallized at the eutectic point of a solution, and it is, therefore, conclusive evidence that in the case in hand bornite and chalcocite were deposited contemporaneously.

It is realized that while these minerals are contemporaneous, they both may be secondary after some leaner copper-bearing minerals. There are certain reasons for suspecting such conditions, the most prominent of which is probably the long period of erosion which the region has undergone since the ore deposits were formed. This long erosional interval would afford time for conditions of oxidation and enrichment to penetrate to exceptional depths in the ore bodies. With this idea in mind careful observations were made as to the depth of the zone of alteration as far as the same could be determined, and the conclusion is that it rarely if ever extends below 175 or 200 feet, the impermeability

FIG. 1. Intergrowth of bornite and chalcocite. × 220. Wall mine. Stippled areas = bornite. White areas = chalcocite. This figure represents a deeply etched section of the two minerals and shows clearly by the etch figure, the lines at right angles to each other in the chalcocite, that the portion of this mineral here seen is a part of a single individual, or crystal, and also brings out the crystallographic relations of these two minerals.

FIG. 2. Intergrowth of bornite and chalcocite. × 40. High Hill mine. Stippled area = bornite. White areas = chalcocite. The peculiar lines in the chalcocite areas are the etch figures and show the coarsely granular condition of this mineral.

of the veins limiting the downward circulation. They and their walls are all exceedingly dense and impervious to water, and the mines all furnish a surprisingly small amount of water, of which by far the greater part comes from the upper 100 feet of the vein. As an example of the tightness of the vein, it may be mentioned that when the Blue Wing mine was unwatered about two years ago, it was found that the air pressure had held the water out of an upraise which had been started from the 266 feet level. The vein material and rock were so tight that the air could not escape even though it was under a pressure of about eight atmospheres. Under such conditions as these, circulation of meteoric waters must necessarily be at a minimum. This tightness of the vein is characteristic of practically all the ore deposits of the Piedmont and southern Appalachian regions.

The relations of ore to the gangue, and of the gangue minerals to each other are strong evidence against the assumption that the two sulphides are secondary minerals. It has been stated before that the ore is so complexly and intricately associated with the gangue minerals that no other conclusion than that of contemporaneous deposition seems tenable. If chalcocite and bornite of the intergrown type are secondary minerals, the whole vein, gangue and all, is secondary.

The minerals of the deposits, both gangue and ores, as a group, with the possible exception of the chalcocite, if they can be said to be characteristic of any one portion of a mineral vein, would probably be typical of the deeper vein zone.[1] These are, so far as has been determined, quartz, calcite, epidote, chlorite, specularite, bornite, chalcocite, a very little chalcopyrite, albite and orthoclase. It must be stated that feldspar of any kind in direct association with the sulphides is rare, but good examples were found at the Seaboard mine, where the feldspar is a plagioclase, probably albite; at the Holloway mine, where both plagioclase and a pink feldspar, which is apparently orthoclase, occur; and at the Copper King mine, where the feldspar is albite. Feldspars,

[1] Waldemar Lindgren, "Relation of Ore Deposition to Physical Conditions, Economic Geology, Vol. 2, 1907, pp. 105–127. W. H. Emmons, "A Genetic Classification of Mineral," Economic Geology, Vol. 3, 1908, pp. 611–627.

however, are very abundant in many of the veins, especially in lean or barren portions. In such occurrences the mineral is generally albite or an acid oligoclase. In certain portions of the veins at the gold mine near Redbank, Virginia, and Holloway mine in North Carolina, pink feldspar occurs in association with quartz so as to strikingly resemble a pegmatite. This is generally not closely associated with the ore, but at times, especially in the Holloway mine, it carries a small amount of the sulphides. It usually is found in barren portions of the vein or as stringers running off from the vein into the country rock.

Origin of the Ores.—The origin of these ores is a more difficult question than one might at first suspect, and is as important as difficult. The country rock is believed to be far too basic to have afforded the vast amount of quartz in the veins. Neither can the underlying quartz porphyry be looked to as the source, since this rock is also older than the veins and is itself cut by numerous quartz veins similar in all respects to those in the andesite and the andesitic tuff, except that they contain but little or no calcite and epidote and probably no copper ores. Some source, therefore, outside of, and much more recent than, the country rocks must be looked for. The only rock in the region which apparently meets the conditions is the granite. This granite is highly quartzose, younger than the rocks in which the ore deposits occur, was not intruded until after a strong schistosity had been imposed upon the andesitic rocks, and is a type of magma the intrusion of which is frequently attended by more or less mineralization in the intruded or adjacent rocks. It is also well able to furnish the acidic material of the veins, and in its effects upon the intruded rocks, through hydrothermal metamorphism, could very well have been responsible for the development of the calcite, epidote, and probably the chlorite. In fact, it appears to be the only rock in the region that could have furnished the feldspars of the veins or have been responsible for the pegmatite-like character of certain portions of some of the veins. It is, therefore, believed that the deformation attendant upon the intrusion of the granite produced the fractures in which the veins now are, and

that the filling of these, both gangue and ores, was supplied by the granitic magma, and that it came in as a phenomenon attendant upon or immediately following its intrusion.

As to the conditions of the deposition, there is little or no positive evidence. Since the ore deposits are confined to the more basic facies of the schists, it may be surmised that the basic character of the rock was a factor of prime importance in the deposition of the ores.

SUMMARY AND CONCLUSIONS.

The rocks of the Virgilina District are greenstone and sericitic schists, which in places have been intruded by granite and gabbro. The intrusive rocks show none of the schistosity of the other rocks. The schists have been derived from a series of volcano-sedimentary rocks of two types—andesite and quartz porphyry, with a preponderating amount of tuffs corresponding to these rock types. Their age is probably early Paleozoic.

The veins are true fissure veins which have a more northerly trend than the schistosity of the country rock, and the filling of which is quartz—about 70 per cent. silica—with local and varying amounts of epidote and calcite. The ore-bearing veins are confined to the more basic portions of the greenstone schists, and the values lie in well-defined ore shoots.

The ore minerals are bornite and chalcocite. They apparently prefer the quartz, but are not confined to any one of the gangue minerals. Bornite is present in slight excess over chalcocite and is apparently of only one period of deposition. Chalcocite is clearly of two periods: One confined to the upper portions of the vein, more recent than, and filling a network of minute fractures in, the bornite; the other contemporaneous and intergrown often crystallographically with it. There is no evidence that any of the bornite is of secondary origin. It is, therefore, believed that in the Virgilina district the greater part of the chalcocite is a primary mineral contemporaneous with the bornite and in no way derived from it, or from any other copper-bearing mineral, by processes of secondary alteration.

REVIEWS

Geology and Ore Deposits of Republic Mining District. By JOSEPH B. UMPLEBY. Washington Geological Survey, Bulletin No. 1, 1910.

In this report is briefly and clearly described the geology of an area of between fifty and sixty square miles adjacent to the town of Republic, Wash. Paleozoic metamorphic rocks were intruded by Mesozoic granodiorite and covered by extensive accumulations of Tertiary lavas and lake-beds. The veins, which cut the Tertiary formations, are composed of quartz, chalcedony, opal, calcite and adularia, with pyrite, chalcopyrite, native gold and one or more undetermined compounds of gold, silver, antimony, selenium and sulfur. These veins are thought to have been deposited by hot waters genetically related to an intrusion of latite porphyry.

The character of this bulletin augurs well for the success of the series of which it is the initial publication and for the future of the Washington State Geological Survey.

F. L. RANSOME.

Elementary Crystallography, being part one of General Mineralogy. W. S. BAYLEY. New York, McGraw-Hill Book Company, 1910. Pp. 241, 311 figs.

The author says in the preface: "The present volume does not pretend to be a treatise on crystallography. It is merely a guide for those attempting to gain some insight into the fundamental principles underlying the science. . . . It is hoped that it may serve as an aid in teaching, but it is not expected to serve as a reference book. . . . It was written for students of mineralogy, chemistry and physics." The scope of the work is clearly defined by the quotation and notwithstanding the (in the writer's opinion) unwise preference given to the Naumann notation over that of Miller, the book is a good one.

A short introduction leads to Part I., Geometrical Crystallography, in which the general laws and facts of crystallography are discussed with the aid of numerous apt illustrations. The chapter on symmetry, though short, presents the essential facts so that one can easily understand the descriptions of the six crystal systems which occupy 102 pages. The crystal forms are classified as holohedral and partial (hemihedral, hemimorphic and tetartohedral). The chapter on Crystal Imperfections dis-

cusses ideal forms, distorted crystals, habit of crystals, deformed crystals, and imperfections in crystal planes due to striations, curvature, corrosion and etched figures, or to irregularity in growth. The symmetry of imperfections and the impurities within crystals (inclusions) are described in some detail. This chapter is well illustrated by 24 figures. In the succeeding descriptions of crystal aggregates and twinned crystals some of the terms used, such as "crystal individuals" and "crystal aggregate" are rather ambiguous. A chapter on the projection and drawing of crystals closes Part I.

Under Physical Crystallography, Part II., are treated the mechanical properties of crystals, including elasticity, tenacity, cohesion, cleavage, gliding, percussion and pressure figures, parting, fracture, hardness and density. Optical properties are next briefly discussed: color, streak, luster, absorption, pleochroism and the phenomena due to refracted light (index of refraction, optical axes and axial angles) being described in the order named. The thermal properties discussed include the transmission and conduction of heat, expansion and contraction, fusion and vaporization. An account of electrical and magnetic properties is followed by paragraphs on solution and etched figures. The author states (p. 221): "All the etch figures are bounded by planes that are subject to the same crystallographic laws as the planes on the crystals of the etched substance." Experience in the measurment of etch figures has shown, however, that they are not bounded by planes but by curved surfaces.

Part III., on Chemical Crystallography, briefly describes polymorphism, morphotropism, isomorphous mixtures and double salts.

The book is very well printed and is notably free from typographical defects. Among the few errors noted is one on p. 121 where fig. 189 illustrating realgar is described as a "crystal of real gas." On p. 68 occurs the rather indefinite sentence that "crystals bounded by open forms cannot be represented by less than two symbols." On p. 188 the incorrect statement is made "Those [minerals] with a hardness of 4 to 5 cannot be scratched with a knife, but can easily be scratched with a good file." If this statement were true an ordinary knife would make no impression on fluorite, whereas every mineralogist has had experience to the contrary. These are, however, but minor blemishes and do not detract from the value of this book, which can be heartily recommended for the purpose for which it is written.

WALDEMAR T. SCHALLER.

The Geology of Water Supply. By HORACE B. WOODWARD, F.R.S., F.G.S. London, Edward Arnold, 1910. Pp. 311, 44 figs.

This little volume, written by a distinguished English geologist, in-

tended primarily for English readers, and naturally drawing most of its facts and illustrations from British authorities and the British Isles, is none-the-less of interest and value to the American student of underground water problems.

The plan followed in the work is that of the general treatise. The author begins with a very brief historical outline which includes mention of a few of the interesting early English and continental water supplies. This is followed by a discussion of the geological and meterological controls of underground water supplies, and this in turn by a discussion of special features and phenomena, such as springs, underflow, types of development works and interference of wells. After these general chapters are three special chapters on the geology of Great Britain from the point of view of the water-yielding values of the geologic formations. Then follow miscellaneous chapters on the water supplies of other parts of the world—a selection of interesting and significant examples from the general literature. Later chapters treat of the quality of water and of mineral waters, and, as appendices, a very incomplete bibliography and a useful glossary and index are added.

The author has had in mind the practical problems before water users, whether those water users are estate owners or municipalities, and has endeavored to introduce as many useful hints as possible. The arrangement is not always of the happiest and a few unimportant editorial errors are noted, but these are slight defects in a generally clear and sufficiently adequate piece of bookmaking.

To the specialist, the most valuable part of the volume necessarily is the general review of other phases of the underground water problem than his own specialty, since any special branch of the science can, of course, receive but casual reference in a general text-book. To the American hydrologist, the chief interest lies in the outline of problems like those of lowering head and decreasing flow,—problems that have long been vital in humid Great Britain, but that are only now becoming acute in parts of arid and semi-arid America.

W. C. MENDENHALL.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

G. F. Loughlin, J. A. Allan and S. J. Schofield.

METALLIFEROUS DEPOSITS.

GOLD AND SILVER.

Cobalt District, Ontario. By S. F. Emmons. Min. & Sci. Press. Vol. 102, No. 11, 1911, pp. 390–396.

The writer deals especially with the genesis of the ores. A short description of the formations and the production of the district is first given, also the general conclusions as to the nature of the ore-bodies as given by other geologists who have worked in the district.

The silver occurs in narrow veins which are Pre-Cambrian in age. The fissures filled with ore-bearing material are true rock fractures or faults of very small displacement. The writer concludes that the extreme narrowness of the fissures in the region may be explained as having been formed at great depth below the surface as it then existed, and under very great pressure, and that these veins were undoubtedly very much wider in their vertical extent. By extensive erosion through long periods, the upper part of these fissures have long disappeared and only the narrow points of these fissure-filled veins now occur. Secondary enriched zones are formed by continued erosion of the upper part of the veins, these zones would become richer with depth and as more of the veins become eroded. Associated with the sulpho-salts, are found arsenic and antimony. The writer states that as the sulphates were carried down by descending solutions, they became reduced to sulphides by the presence of unaltered sulphides. The presence of native silver may be accounted for by the reduction of the sulphide in the presence of some carbonaceous material. Some graphite is present in this region. A.

The Nevada City Mining District, California. By A. H. Martin. Min. Sci. Feb. 9, 1911, p. 160.

The country rock of the district is principally of igneous character and consists of granodiorite, diabase, diorite gabbro, porphyrite

pyroxenite and peridotite, with the latter two formations altered often to serpentine. The productive veins generally occur in vicinity of the granodiorite and metamorphic slate contact. S.

The Homestake Mine, South Dakota. By CLARENCE C. SEMPLE. Eng. & Min. Jour. March 25, 1911.

Describes geology and ore occurrence with notes on methods of mining. S.

Ore Occurrence at the Doone Mine. By P. B. MCDONALD. Eng. & Min. Jour. April 15, 1911, p. 757.

The gold occurs in quartz masses and veins in Huronian sediments and Keewatin schists. Some of the gold is visible but most of it is disseminated, principally through the quartz, although it also occurs in the country rock. S.

Die Goldbergbaue in den Hohen Tauern. By F. BECKE. Vortrag. Schriften des Vereins zur Verbreitung naturwissenschaftlicher Kenntniss in Wien. 1909, 49 Bd., pp. 265–287. (Geol. Zentralb., XV, 12, 1911, p. 570.)

Describes eight mines in two "Zentralgneisskerne." The ore, mostly sulphide with a little free gold, occurs in veins along the margins of the gneisses. L.

Pay Streaks at Nome. By T. M. GIBSON. Min. & Sci. Press. Vol. 102, No. 12, pp. 424–427 and No. 13, p. 462–

There are now seven recognized horizons of beach deposits between the foothills and the sea. To these the writer adds another beach deposit which has been located to the west end of Nome, and 45 feet below the present level of the sea. This is called the "off-shore beach." These various beaches are known as the "present beach," "second beach," "submarine beach," "intermediate beach," "Monroeville beach," "third beach," "fourth beach," and "off-shore beach."

A description of each gives the extent and nature of the placers. A.

Tonopah Geology. By J. E. SPURR. Min. & Sci. Press. Vol. 102, No. 16, pp. 560–562.

Outlines his results of recent study in this region and thus supplements his work of 1902. The "earlier andesite" is the oldest rock but proves to be a trachyte flow highly altered to quartz, sericite, and adularia; the lower part of flow is glassy. This was followed by rhyolite flows and later by andesite flows. The veins are divided into three periods according to age. The oldest veins followed the trachyte, and are the most important, consisting of quartz with silver and gold. The veins of the second period followed the West end

rhyolite intrusion and are grouped into (1) barren quartz veins, (2) tungsten-bearing veins, (3) mixed quartz and adularia veins, and (4) quartz veins like those in the first period. The third period of vein formation followed the Tonopah rhyolite intrusion and are quartz veins containing lead, zinc and copper sulphides. All the veins in the district formed at shallow depths. A.

IRON.

Characteristics and Origin of the Brown Iron Ores of Camaguey and Moa Cuka. By W. L. CUMMINGS and B. L. MILLER. Trans. Am. Inst. of Min. Eng. No. 31, p. 247.

Full description of the deposits with a discussion as to origin. S.

The Occurrence, Origin and Character of the Superficial Iron Ores of Camaguey and Oriente Provinces Cuka. By A. C. SPENCER. Trans. Am. Inst. of Min. Eng. No. 51, p. 231.

The ferruginous deposits of the Cukitas Mayori and Moa districts, Cuka, occur as surficial mantles covering extensive plateau-like areas underlain by serpentine rock from which these residual brown ores were formed by decomposition of the serpentine. S.

The Origin of the Iron Ores of Central and Northeastern Cuka. By C. K. LEITH and W. J. MEAD. Trans. Am. Inst. of Min. Eng. No. 51, p. 217.

The ores of Moa and Moyari are residual or mantle deposits resulting from surface alterations in place of serpentine rock. The source of the Camaguey deposits is preferably attributed to the alteration of limestone. S.

The Iron Ore Deposits of the Moa District, Oriente Province Island of Cuka. By JENNINGS S. COX. Trans. Am. Inst. Min. Eng. No. 51, p. 199.

The ore consists of a mantle of average thickness of 18 feet, lying upon serpentine rock and covers an area nearly continuously of 70 sq. miles. In the lower levels the ore is practically all limonite, but near the surface it has parted with some of its water and oxygen and hematite and magnetite predominate. S.

The Mayari and Moa Iron Ore Deposits in Cuba. By C. W. HAYES. Trans. Am. Inst. of Min. Eng. No. 51, p. 239. S.

Die Eisenerzlagerstätten Bosniens und der Herzegovina. By F. KATZER. Berg und Huttenwesen. Jahrb. d. k. k. Montanist Hochschulen zu Leoben und Pribram. Bd. LVII., 1909, H. 3/4, pp. 173–330.

General descriptions of all known deposits in the two regions. The most important deposits are siderite with galena and pyrite in slate at

Ljubia; siderite veins in sandstone at Stara Rjeka; metasomatic iron ore in limestone at Drenovac, oxidized iron ore at Krijava. L.

Die Spateisensteinlagerstätten des Zipser Comitates in Oberungen. By W. BARTELS. Archiv. f. Lagerstättenforschg. Heft 5, 1910, 113 pp., with 9 plates and 22 text figures.

Describes the geology and derivation of the several rock formations (metamorphic sediments and diorite-schist), and the two groups of veins (iron carbonate accompanied in some places by copper sulphide, and in others by tourmaline), which are believed to be genetically related to the diorite-schist, and to be of post-Carboniferous age. A history of mining in the district is given. L.

Specular Hematite Deposits, Planet, Arizona. By W. E. UPHAM. Min. & Sci. Press. Vol. 102, No. 15, pp. 521–523.

The specular hematite occurs in thick beds of Pre-Cambrian quartzite. Towards the top of the beds the iron ore occurs in small fissures, gradually increasing in amount until at the bottom the quartzite is entirely replaced by specular hematite, which has a thickness of 15 feet. A large part of the iron is believed to have come from the leaching out of chlorite which is interstitial with the rounded grains of quartz.

Seldom is the limestone found replaced by hematite. A.

TELLURIUM.

Canadian Tellurium-Containing Ores. By D. D. CAIRNES. Can. Min. Jl. Vol. 32, No. 7, pp. 215–219.

Briefly describes the occurrence of tellurium minerals in the Yukon and British Columbia, and gives a compilation of the main facts concerning other Canadian localities for the ores of tellurium. With the exception of tetradymite, all these minerals occur in veins filling fissures or formed by metasomatic replacement. The veins are usually quartz, sometimes calcite and rarely ankerite and sericite. With one possible exception, all the veins are in or near igneous rocks. A.

TIN.

Tin in Malaya. By F. D. OSBORNE. Min. & Sci. Press. Vol. 102, No. 11, 1911, pp. 400–402.

The amount produced in the last 20 years in Federated Malay States has averaged 43,685 tons yearly. The deposits are all alluvial. The rock is a white marble of unknown age, chiefly occupying the floor of the valley, surrounded by granite, forming mountains. The tin deposits are well rounded and occur in fissures near the contact of the

limestone and the granite; and also in holes 1,300 feet above the valley floor. The writer believes the tin to have come from the erosion of lodes in the granites and schists. Some of the lodes occur in fissure veins in schist and slate which overlies the granite. A.

LEAD.

Die Erzlagerstätten am Shauinsland in Südwestlichen Schwarzwalde. (Eine Untersuchung auf dem Gebiete der chemischen Geologie.) By FRIEDRICH SCHUMACHER. Zeitschrift für praktische Geologie. Jan.–Feb., 1911.

The author gives a very detailed account of the above deposits. S.

NON-METALLIC DEPOSITS.

CLAYS.

Clays and Clay Industry of Washington. By SOLON SHEDD. Published by the State College of Washington. Pullman, June, 1910. Pp. 324, plates XLII.

This volume contains much information concerning the nature distribution and technology of clays in the state of Washington. In Part I. are discussions of the chemical and physical properties of clay in general, with a closing chapter of suggestions to the prospector. Part II. deals with the general technology of the clay industry. Part III. considers by counties, the principal known occurrences of clay in Washington, its laboratory examination and its present uses.

OIL.

The Petroleum Fields of Colorado. By ARTHUR LAKES. Min. Sc. March 23, 1911, p. 311.

The Geology of the Boulder Oil Field. By ARTHUR LAKES. Min. Sc. March 30, 1911, p. 341.

Geology of the Florence Oil Field. By ARTHUR LAKES. Min. Sci. April 6, 1911, p. 367.

The Geology of Wyoming Petroleum Deposits. By ARTHUR LAKES. Min. Sci. April 20, 1911.

Oil is found at several horizons, principally the Dakota, the Jurassic and Permian or Permo-Carboniferous strata which has been folded into anticlines and quaquaversal domes. favorable for the occurrence of oil and gas. S.

OIL AND GAS.

Petroleum and Natural Gas—1859 to 1911. Supplement to the Oil and Gas Journal. March 2, 1911.

Tabulated statistics showing for each year the number of wells

drilled, total production and value, daily average production, etc., for the United States as a whole and for the separate oil regions in the United States. L.

Geology of the Sargent Oil Field (California). By W. F. JONES. Univ. of California Publications. Bull. of Dept. of Geology. Vol. 6, No. 3, 1911, pp. 55–78, Pls. 13–18.

Gives brief descriptions of the several formations, summarizes the geologic history, describes the occurrences of oil, and mentions other materials of minor economic value. L.

Sopra alcuni asfalti di Sicilia. By A. COPPADORO. Rass. Min. XXXIII., No. 1, pp. 1–3, Torino, 1910.

WATER.

Surface Water Supply of the United States, 1909, Part X. The Great Basin. Prepared by E. C. LARUE and F. F. HENSHAW. Water Supply Paper 270, U. S. Geol. Survey. 1911, pp. 192, 5 pls.

Well-drilling Methods. By ISIAH BOWMAN. Water-Supply Paper, U. S. Geol. Survey. 257, 1911, 139 pp., 4 pls., 25 text figures.

Designed for the needs of drillers and others interested in the development of underground resources. Describes the occurrence of oil and gas in different parts of the United States so as to enable drillers to select well sites with a definite idea of the rock formations that may be encountered. Gives a short account of the development of well construction and describes methods of drilling and boring in detail. The illustrations include well sections and cuts of the different tools employed.

REGIONAL REPORTS.

Geology of Berners Bay Region, Alaska. By A. KNOPF. Bull. U. S. Geol. Survey. No. 446, 1911, pp. 58, with 2 plates and 4 figures.

Outlines geography and geology, describes types of ore bodies (fissure veins, stockworks and stringer lodes), mineralogy and origin of the ore bodies, and gives details of individual mines and prospects. The ore bodies are believed to persist without diminution in values below the depth of profitable extraction. L.

Geology of the Pegmatites and Associated Rocks of Maine. By E. S. BASTIN. Bull. U. S. Geol. Survey. No. 445, 1911, pp. 152, with 19 plates and 8 figures.

The first 45 pages, dealing with geology, character and origin are practically a duplicate of a recent paper by the same author in the *Jour. of Geology*. Pp. 46–117 contain local descriptions; pp. 119–148 descriptions of economically important minerals (feldspar, quartz, mica, tourmaline, beryl and topaz). L.

Mineral Resources of Johnstown, Pa., and Vicinity. By W. C. PHALEN and LAWRENCE MARTIN. U. S. Geological Survey. Bull. 447, 1911, 142 pp., 7 pls., 22 text figures.

A full discussion of the geology of this important coal-bearing region, with descriptions of its mineral resources. Coal and clay, the most valuable resources, are treated in detail by districts.

Geologische Untersuchungen in den Erzdistrikten des Vilajets Trapezunt, Kleinasien. By F. KOSSMAT. Mitt. d. Geol. Gesell. Wien. Bd. III., 1910, pp. 214–284, with 10 text figures.

Describes geology, a series of alternating sediments and volcanics, and the ore deposits. The latter include, A. Sulphide deposits (veins and impregnations of copper, silver-lead, and zinc, and contact deposits in limestone of copper and silver-lead ores); B. oxidized deposits of copper, manganese, and iron. L.

ORE DEPOSITS.

Die Lagerstätten der nutzbaren Mineralien und Gesteine, nach Form, Inhalt, und Entstehung dargestellt. Bd. I., Hfte. 2; Magmatische Erzausscheidungen. Kontaktlagerstätten. Zinnsteinganggruppe und Quicksilberganggruppe. By F. BEYSCHLAG, P. KRUSCH and J. H. L. VOGT. (Geol. Zentralb. Bd. 15, No. 13, 1911, p. 616.) Stuttgart, 1910, pp. 239–509. Price M. 8, 60.

The first group contains: A—chromite in peridotite and serpentine, titanomagnetite and ilmenite in gabbro, labradorite rock, augite- and nepheline syenite, etc., iron and apatite-iron ore in acid eruptives; B—nickel-pyrrhotite group and intrusive sulphide deposits; C—nickel-iron in peridotite, nickeliferous iron in basalt, platinum in peridotite, and copper and gold in eruptive rocks. The contact deposits comprise those of the Kristiana region, Banat, Ural, Elba, Piedmont and the United States and Mexico, including the Mn deposit of Långban, the Zn-Mn deposit of Franklin Furnace, Broken Hill, Kupferberg and Reichenstein, and tinstone-bearing contact deposits. Review of the literature is given for each group. L.

Ore Deposits and Underground Water Circulation. By G. W. MILLER. Min. Wld. Vol. 34, No. 9, pp. 483–484; No. 12, pp. 631–633; No. 14, pp. 733–735; No. 15, pp. 777–780.

Gives several figures which show how the ground water level may change according to the nature of the rock, or by orogenic movements. The writer summarizing in a few lines, states that when rocks are saturated the waters flow from places of greater pressure to places of less pressure; gases also obey the same law, and move from places of high temperature to places of lower temperature. The more con-

tinuous the opening, the more rapid will be the flow, which also increases with the size of opening. Increase of temperature causes water to enter very small fissures. A.

GENERAL.

Geology Applied to Mining. By F. A. LINFORTH and E. B. MILBURN, Eng. & Min. Jour. April 1, 1911, p. 664.

Emphasizes the value of geological work in the location of new ore-bodies. S.

Mineral Resources of the United States, 1909. U. S. Geol. Survey.

Advance chapters on antimony, arsenic, bismuth, and selenium; gold, silver, copper, lead and zinc in the eastern United States; quicksilver; mica; anthracite coal; quartz and feldspar; slate; platinum and allied metals; fluorspar and cryolite; fuller's-earth. The production in 1909 of gems and precious stones; sandlime brick; iron ore, pig iron and steel; gypsum; phosphate rock; graphite; abrasive materials; barytes and strontium; chromic iron ore; manganese ores; magnesite; borax; bauxite and aluminum. L.

SCIENTIFIC NOTES AND NEWS[1]

In the editorial entitled "Some Probable Results from Conservation" which appeared in Volume VI, Number 3, of Economic Geology, the signature of Mr. Winchell was inadvertently omitted.

Letters from Bailey Willis and members of his party announce their safe arrival and the beginning of geologic field work in Argentine Republic early in March.

Dr. and Mrs. Ralph Arnold, of Los Angeles, sailed on the *Mauritania* April 5 for London. They expect to spend about three months on the continent and Mr. Arnold may go as far east as the Baku oil field.

F. E. Matthes, of the U. S. Geological Survey, went to the University of Michigan, Ann Arbor, the middle of April, to give a six weeks' course of lectures on glaciology.

Mr. A. G. Maddren, of the Division of Alaska Mineral Resources, U. S. Geological Survey, sailed from Seattle, May 6, accompanied by J. M. Jessup, of the Smithsonian Institution, to join the large international party surveying the boundary between Alaska and Yukon Territory. He will study the geology of the boundary from the Porcupine River north toward the Arctic coast.

The Washington Academy of Sciences and the Washington Society of Engineers held a joint field meet April 28–30 in the Dismal Swamp, near Norfolk, Va. The excursion was so arranged as to be convenient for ladies. The party included large delegations from the Forest Service and Geological Survey. Among the papers read on the steamer going down the Potomac

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

were two of geologic interest: "Five Minutes of the Geology of the Dismal Swamp," by E. W. Shaw; "Peat Deposits," by C. A. Davis. While in the swamp the members of the party were the guests of the Lake Drummond Canal and Water Company.

SIR JOHN MURRAY addressed the Washington Academy of Sciences at the New National Museum, April 18, on "The Ocean."

AT THE ANNUAL MEETING of the State Geologists held in Washington, April 18–20, at the invitation of the Director of the United States Geological Survey, the following states were represented: Alabama, Eugene A. Smith; Connecticut, Wm. North Rice; Georgia, S. W. McCallie; Illinois, Frank W. DeWolf; Kansas, Erasmus Haworth; Michigan, R. C. Allen; Mississippi, E. N. Lowe; Missouri, H. A. Buehler; Nebraska, E. H. Barbour; New Jersey, H. B. Kümmel; North Carolina, Joseph Hyde Pratt; Ohio, J. A. Bownocker; Oklahoma, Chas. N. Gould; Oregon, John H. Lewis, state engineer; Pennsylvania, Geo. W. McNees; Rhode Island, Chas. W. Brown; Virginia, Thos. L. Watson; Washington, Henry Landes; West Virginia, I. C. White; Wisconsin, W. O. Hotchkiss.

The State Geologists were entertained on Wednesday eve, April 19, by the Geological Society of Washington at a smoker held at the Cosmos Club and on Thursday evening at a reception by Director and Mrs. G. O. Smith.

NEARLY 80,000,000 acres of territory—possibly coal bearing—are yet to be classified by United States Geological Survey.

The government has a gigantic task in hand in the classification and valuation of its coal lands in the West. These lands are probably the nation's greatest direct asset, not even excepting the millions of horsepower latent in the rivers on the public lands. During the last two years the United States Geological Survey has examined in great geologic detail over 15,000,000 acres of the western coal lands, and in the month of March it classified and appraised 1,220,748 acres, with a valuation of $37,971,740. There still remains withdrawn, however, 78,152,808 acres await-

ing classification and valuation. The following table shows the states in which these lands are situated:

COAL LANDS WITHDRAWN AND AWAITING CLASSIFICATION APRIL 1, 1911.

	Acers.
Arizona	118,718
California	239,903
Colorado	5,866,763
Idaho	8,266,509
Montana	21,393,613
New Mexico	2,532,038
Nevada	92,141
North Dakota	18,215,384
Oregon	3,711
South Dakota	2,375,263
Utah	6,128,923
Washington	2,207,967
Wyoming	10,711,875
Total area	78,152,808

DR. ROLLIN T. CHAMBERLIN, of the University of Chicago, sailed for South America on March 20, to engage in geological work on some of the metamorphic rocks of southeastern Brazil and on certain portions of the Andes.

AT the Normal College, New York City, Charles T. Kirk, instructor, has been promoted to be assistant professor of geology.

DR. LUCIUS L. HUBBARD has been appointed regent of the University of Michigan. He has been instructor in mineralogy at the State Mining School at Houghton, Mich., and was state geologist from 1893 to 1899.